The term 'highline'—often inappropriately referred to as a 'Tyrolean'—refers to a system that uses a track rope (mainline) to suspend a load over a span. Highlines can be much more practical for rescue work than is commonly assumed. However, many people do not appreciate the high levels of force that can be easily placed on the track rope if some key principles are not taken into account. This has led to highlines being set up with excessively low safety factors through the use of ill-considered rigging concepts. To increase the safety of using highlines, practitioners must first obtain the proper in-depth training in basic physics and rigging principles, and also have access to the appropriate equipment. With this approach, rescuers can rig effective, efficient and safe highlines that can be more practical than other techniques available in certain applications.

The Kootenay Highline System (KHS):

In 1985, in the province of British Columbia, serious thought and consideration was given to the rigging and operating principles of highlines. This work led to the development of the key concepts and principles of the Kootenay Highline System. Since then, several practical variations have also been developed, such as the English Reeve, the Norwegian Reeve and the drooping highline variations. In addition, the KHS has been tested in several variations and its concept of belaying with the taglines was demonstrated as early as 1986. This cannot be said for most of the other highline techniques in use today.

Though there are many ways to categorize highlines, for the KHS a distinction is drawn between horizontal highlines, sloping highlines and steep highlines. A horizontal highline is one that has no more than a 10º change in angle between end stations. A sloping highline has more than 10º but no more than 45º angle between end stations; and a steep highline has an angle greater than 45º.

To really understand the KHS is to realize that there is no 'one-correct-way' to rig it. Each KHS is built using the deliberate application of key rigging and operating principles and concepts to the specific rescue situation at hand. While some specialized gear—such as Prusik Minding Pulleys and Kootenay Carriages—may help the efficiency of operating a KHS, it is by no means essential, and can often be substituted as long as the replacement equipment can meet the same performance and safety criteria.

Key KHS Principles:

This handout provides a overview of the primary rigging and operating principles of the KHS up to 100 metres (m) in length. For extreme highlines (i.e. those greater than 100m in length), additional considerations that must be taken into account such as formulas and calculations are not covered in this handout.

Rescue teams wishing to perform safe and effective rescues with this highline technique must have a thorough understanding of all of the KHS principles, the most important of which are:

1. Minimize any loss of breaking strength in the highline's track rope by having no knots or sharp bends in it. Also, anchor the fixed end of the track rope with a high strength tie-off (Figure 1) or a Kootenay Carriage with the pins inserted.

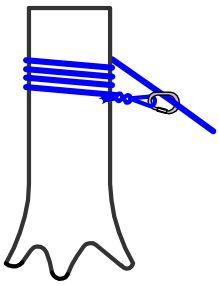

Figure 1: High Strength Tie-Off

2. Attach the tensioning pulley system to the track rope with a gently acting slipping clutch to prevent over-tensioning (Figure 2). At the present time, Tandem 8 mm 3 wrap Prusik Hitches are used. Mechanical rope clamps such as Gibbs™ or handled ascenders are unacceptable.

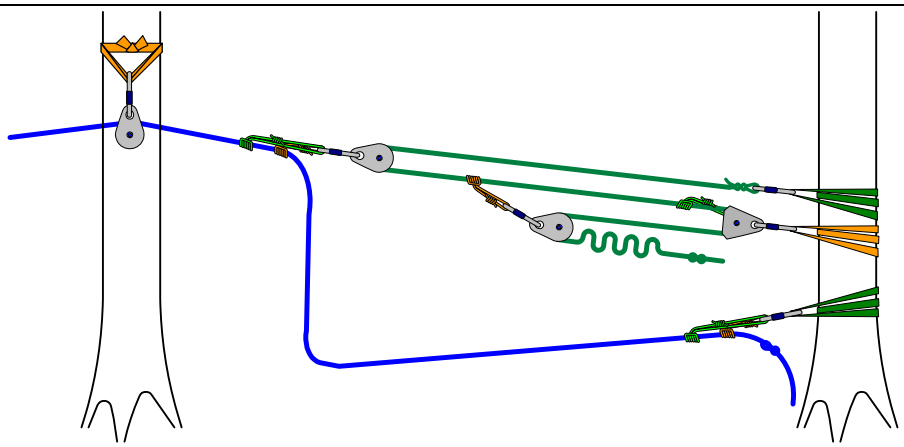

Figure 2: Tensioning System for a Single Track Rope

3. Attach the load by hanging it from a device capable of sustaining multiple direction forces, such as a Kootenay Carriage, a solid pear shaped or round rigging ring, or equivalent. There are many ways to accomplish this. Consideration must also be given as to whether or not the load will be suspended from one or two attachment points and if the tagline will be one continuous rope or whether two separate ropes will be used. Some examples of various combinations are shown in Figure 3.

4. Rig the taglines to handle shock forces in case of track rope failure by the use of Prusik by-passes at end knots and managing the taglines with Tandem 8 mm 3 wrap Prusik Hitches—as per Prusik Belaying— attached to suitable end point anchorage. At the load, the taglines should be attached directly to the device capable of sustaining multiple direction forces, as is shown in the examples in Figure 3, and <u>not</u> to the load itself.

5. The KHS is intended to be operated with a Static System Safety Factor of 10:1 or greater on the track rope. If lack of clearance requires minimal deflection (sag), then the track rope may be doubled or quadrupled in order to maintain the principle of a minimum 10:1 safety factor.

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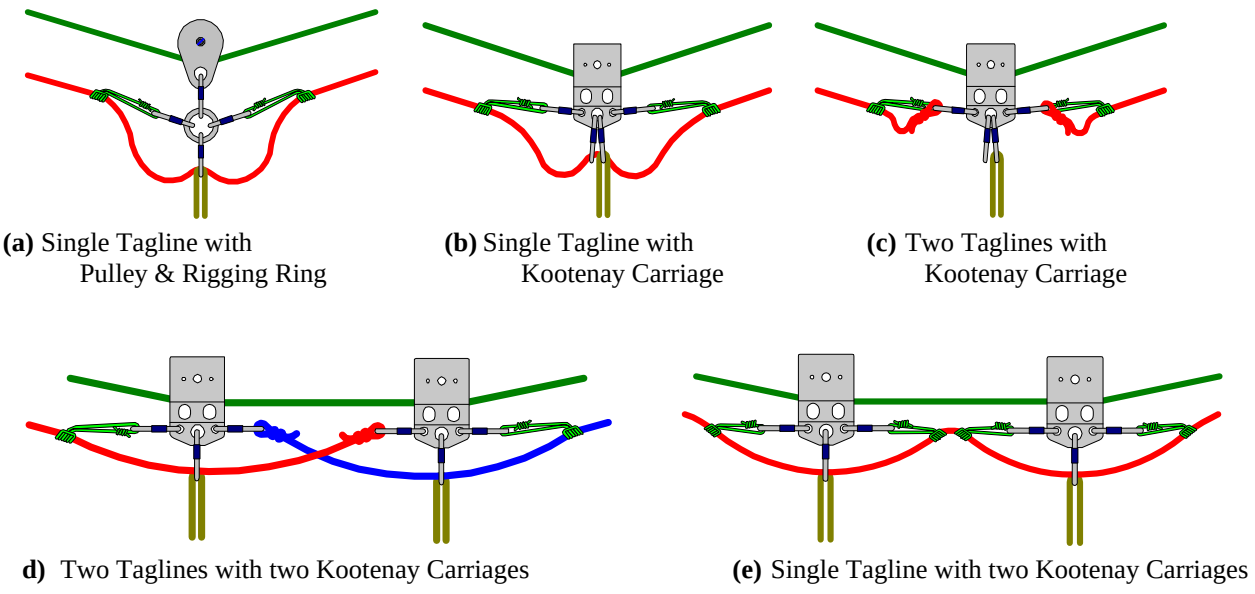
Additional KHS Principles:

While the first five points describe the most important rigging principles of the KHS, the following principles are also important, but may or may not apply depending on the specific rigging requirements of the highline being set up:



(a) Single Tagline with Pulley & Rigging Ring

(b) Single Tagline with Kootenay Carriage

(c) Two Taglines with Kootenay Carriage

d) Two Taglines with two Kootenay Carriages

(e) Single Tagline with two Kootenay Carriages

Figure 3: Examples of Methods to attach the load and tagline(s) to central attachment point

6. Consistent with the principle of minimizing any loss of strength in the track rope, any pulleys supporting the track rope must be of a large enough diameter. This is especially true for any track rope support pulleys at the tensioning end of the highline. The track rope tension may be adjusted from time to time, which will result in considerable movement of the track rope over the support pulley. At the fixed end of the track rope, any support which has a smooth, large diameter curved surface would do, since the track rope will not move significantly at this end during any adjustment of track rope tension.

7. The pulley from which the load is supported, also needs to be of large enough diameter or proper configuration to minimize the loss of any track rope breaking strength.

8. The track rope and taglines should have their own independent anchor systems with a breaking strength greater than or equal to the breaking strength of the ropes. For example, an 11.1 mm track rope with a breaking strength of 30 kiloNewtons (kN) must have an anchor system strength of 30+ kN. If the track rope is doubled (i.e. two 11.1 mm ropes), then the minimum anchor system breaking strength must be 60+ kN.

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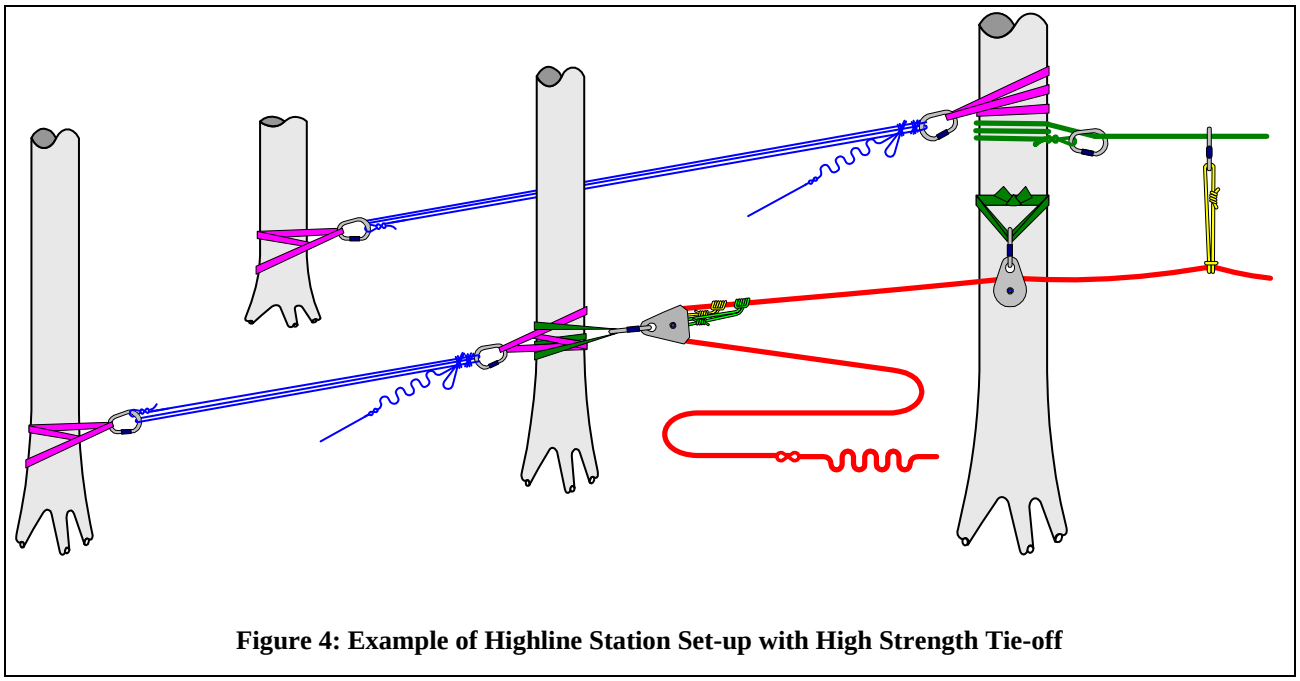

Figure 4: Example of Highline Station Set-up with High Strength Tie-off

9. Both the track rope and taglines must be able to run freely through pulleys or rollers without contacting the ground, cliff, or other obstacles.

10. On highline spans greater than 30m or so, tagline hangers should be employed to support the taglines thereby minimizing excessive tagline slack. A tagline hanger can be easily be constructed using a sling of accessory cord, Girth Hitch it around the tagline and clip it to the track rope with a non-locking carabiner at regular intervals as required (see Figure 4).

11. The attendant (if used) and patient are connected to the carriage(s) with a back-up in addition to their primary support. If the attendant's primary support is an attachment directly to their harness, then the harness connection should be such that it would keep the attendant upright and maintain their position relative to the patient in the event of a track rope failure.

12. The tension in the track rope should never exceed one tenth of the track rope's breaking strength to maintain a minimum 10:1 Static System Safety Factor. Some general guidelines have been developed for the proper tensioning of the KHS. These 'general' guidelines are based on the knowledge gained from a series of trials to see how much force can be applied to a track rope with various combinations of pullers and pulley system mechanical advantages. With the following suggested guidelines, 'average' rescuers should not be able to over-tension the track rope (i.e., to more than one tenth its breaking strength). Variation between people's pulling ability must be taken into account and corrected for. The guidelines for 11 mm (30 kN breaking strength) track ropes are as follows:

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→ It is important to distinguish between tensioning the track rope with and without a load on it. With no load placed on the system, have only one person pre-tension the system by pulling on a 2:1 pulley system. Pulling on the pulley system assumes 'normal' pulling; the rope is not wrapped around any part of the puller's body, and once the puller reaches his/her maximum pulling ability, no additional attempts are made to 'heave-ho' more tension into the system.

→ With the load at center-span, the maximum force that can be applied to the track rope is a multiple of 12 (i.e., the number of pullers times the mechanical advantage is less than or equal to 12). This means, for example, that 6 people can pull on a 2:1, 3 people can pull on a 4:1, or even 2 people can pull on a 6:1. The same guidelines apply to single, double, and quadruple track rope tensioning.

If the track rope is 12.5 mm in diameter (40+ kN), the sample principles apply except that a multiple of 18 can be used instead of the multiple of 12 described above. Therefore, 9 people can pull on a 2:1 (though usually impractical), 6 people can pull on a 3:1, 3 people can pull on a 6:1 or 2 people can pull on a 9:1.

It is important to recognize, understand and take into account that there will be differences in the capabilities between people's pulling ability, as well as differences in actual versus ideal mechanical advantage between pulley systems.

13. When double or quadruple track ropes are used to either reduce sag or enable larger loads to be transported, it is important to ensure that there is equal tension in each track rope. This can be accomplished with the use of pulley systems-in-series pulling on all track ropes. Figure 5 is an example of a compound 6:1 pulling on each track rope of a double track rope highline. If these were 11 mm track ropes, then a maximum of 2 people would pull on this pulley system as per the criteria outlined in #12 above. Note the connector strap between the pulleys connecting the Tandem Prusiks to each track rope. This is used so that the integrity of the pulley system will be maintained, even if one of the track ropes were to fail. Additional anchorage of the track ropes with Tandem Prusiks is

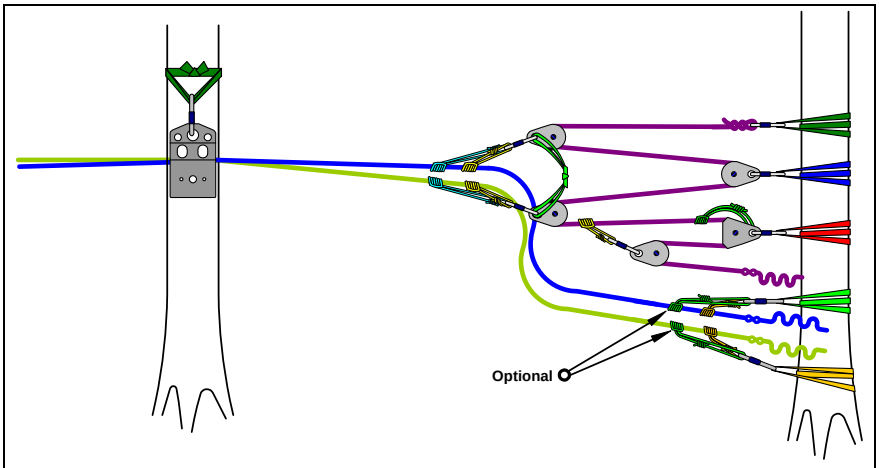

Figure 5: Example of Pulley System Set-up to Apply Equal Tension to each Track Rope in a Double Track Rope System

Graphics created by Earl Fröm

optional, and mostly used for drooping highlines or those highlines that require the tensioning system to be reset during the operation.

14. Once the load has passed mid-span and begins to travel towards the destination station, a pulley system on the tagline may be required to help pull the tagline and load into the station. This can be easily done by making a simple 3:1 pulley system out of the tagline (Figure 6). Note that the Tandem Prusiks are still in place to maintain the belay capability of the tagline.

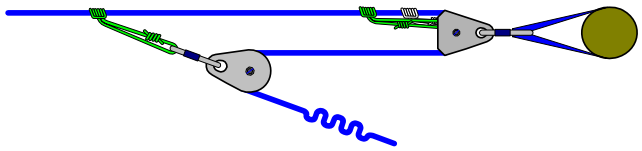

Figure 6: Example of Pulley System attached to Tagline

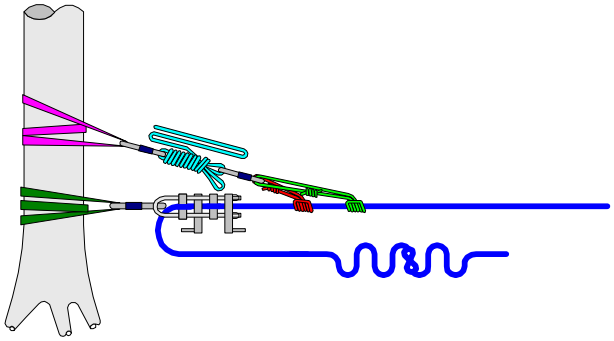

Figure 7: Use of a Brakerack on the Tagline

15. For sloping highlines, the speed of descent out of the top station must be controlled (Figure 7). A brakerack can be used at this station for additional control. Tandem Prusiks with an LR Hitch are still placed on the tagline in front of the brakerack so that the tagline can still act as a belay in the event of a mainline failure.

Operational Logistics:

There are many ways to set up a highline. Therefore, any examples in this handout are not to be construed as 'the way' of how to set up a KHS. Many factors must be taken into consideration, and rescuers should practice various ways of setting up highlines so as not to resort to just one method. The key variables that determine how a KHS will be set up are: the span, the angle between end stations, length of ropes, available equipment, access limitations to either side, the terrain, number of people, the size and location of the load, and communication considerations.

Often the greatest difficulty in setting up a highline is getting the first line across. Pre-planning which equipment needs to be at each end station, and once the first line is across, prioritizing which ropes and equipment will be ferried back and forth is the key to efficiency. If the span is very short, then the track rope and taglines themselves may be tossed to the other station. However, if this can not be done, then either a messenger cord or a pilot line may need to be put in place first. A messenger cord is a small diameter cord capable of hauling the ropes across, whereas a pilot line is an even smaller diameter cord—like that used for a line gun—which is used to pull a messenger cord in place. There are various ways in which the first line (or rope) can be placed across the span: it may be carried or walked over; a cord may be lowered from each end station and then tied together; it may be thrown across; shot across with a line gun, compound bow, slingshot, or solid or air fueled rocket, or it may be transported across with a water craft in river rescue. These are just a few examples and there are many more options other those than just these listed here.

Graphics created by Earl Fröm

Example of a KHS Set-up:

Again, there are numerous ways to set up a highline. The following example is by no means comprehensive and does not do justice to some of the logistical priorities, operational movements for smoothness and communication requirements which lend to efficiency and expediency. This is best learned through competent instruction and practice in setting up highlines a variety of ways. The following example assumes that this is a single track rope, two tagline highline; the rescuers have pre-planned which equipment will go to which end station. For clarity, the end stations are called Station One and Station Two:

1. From Station One, establish a messenger cord between end stations that is twice the length of the span. Tie a 'floating middle tie' (e.g. butterfly knot) in the middle of the messenger cord.

2. Clip the track rope to the floating middle tie and have Station Two pull it over by pulling in the messenger cord. Once the Station Two receives the track rope, they can quickly attach a Prusik Hitch a few metres from the end of the track rope and clip it to an anchor (e.g. a sling in a tree where the high strength tie-off will go). Station Two then clips their tagline to the floating middle tie to be pulled back across by Station One. If the span requires it, tagline hangers are put on at regular intervals; feeding out enough tagline to allow it to hang below the track rope.

3. Station One now receives Station Two's tagline, and connects it to Station One's tagline and carriage unit which was set up while they were waiting for Station Two's tagline to arrive. (Note: the messenger cord should be left across the span for the duration of the operation though it can be placed out of the way on either side).

4. Station Two now proceeds with tying a high strength tie-off with the track rope and should advise Station One when this has been completed. They can also set up a tagline/belay anchor system, as well as any backties required (for both the track rope and tagline anchor systems).

5. Station One completes any rigging required while Station Two is working on their end. This may include setting up the tensioning system, tagline and track rope anchor systems, and placing support pulleys. Once Station Two has completed the high-strength tie-off, Station One can complete the pre-tensioning of the track rope and get the attendant/patient ready.

6. Once all system components are checked, the patient and/or attendant can be attached to the carriage unit and communication set-up to start sending them across the highline.

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