Litter Raises/Lowers on Slopes:

Litter transport up (or down) steep embankments is an often used rope rescue technique for transporting patients involved in 'over-the-side' vehicle accidents. In mountainous terrain, this technique may also be referred to as a scree evacuation. Usually there are three or four litter bearers, and the mainline is attached to the head end of the litter. While there are several different ways to rig a litter raise/lower on a slope, consideration must be given to the escalating tension that the mainline is subjected to as the slope angle increases. If our objective is to operate at or above a static systems safety factor (SSSF) of 10:1, then there is a limit on how steep we can go using this technique.

What operating guidelines do we use in determining our maximum slope angle for a given rope type and number of litter bearers? While it is impractical to take a calculator or a set of force tables to the rescue, some 'rules-of-thumb' can be developed with a basic understanding of the relationship between mass, force, and slope angle.

The graphical use of force vectors provides both a reasonable level of force approximation and a better understanding of, and appreciation for the forces that could be produced within the system. Recognizing that *many* variables affect the resulting force or tension in the mainline, some assumptions need to be made to simplify it toward the 'rule-of-thumb' level. For this discussion, they are:

1. Each person (either rescuer or patient) has a mass of 100 kilograms, including equipment,
2. Each litter bearer walks with their body positioned perpendicular to the slope,
3. The rope angle is the same as the slope angle, and
4. The path traveled by the litter bearers is that of the fall line.

There are basically three forces acting on the system (Figure 1):

mg the mg-force due to gravity acting on the combined mass of the litter bearers, patient and equipment;

R the resisting force of the ground on which the litter bearers walk; and

T the tension in the rope.

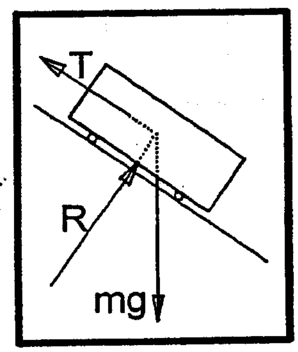

Figure 1

Statically, these forces are in equilibrium, in other words, the forces have resolved themselves. Each of these three forces can be represented graphically as force vectors since they have both magnitude and direction. We know the direction in which these three forces are applied, and we also know the magnitude of the mg-force since we know the total mass involved. By selecting a scale for force, such as 1 centimetre (cm) = 1 kiloNewton (kN), we can draw the force vectors to scale, and then determine the **T** in the rope by physically measuring that force vector. Since the system is in equilibrium, the combined effect of the **R** and **T** force vectors result in an opposite and equal force to the **mg** vector, thereby countering its effect.

To draw the vectors, start with the **mg** force vector, indicating both its *magnitude* and *direction* (Figure 2); next draw in the vectors which counter the effect of **mg**; draw the resistance **R** vector (Figure 3)—in this case you know only its direction—and have the tail of the **R** vector start at the tip of the **mg** vector. Draw the **T** vector from the tip of the **R** vector, and draw it parallel to the slope angle until it intersects the tail of the **mg** vector (Figure 4). The magnitude of the **T** vector—which is the tension in the rope—is determined by measuring its length, and comparing it to the scale to which you drew the **mg** vector. For example, if you used the above scale, and you drew the **mg** vector 2 cm long representing 2 kN of force, then if the resultant **T** vector is 1.2 cm in length, then the corresponding force would be 1.2 kN.

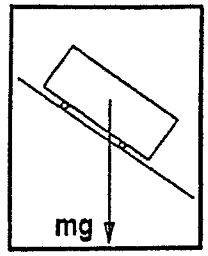

Figure 2

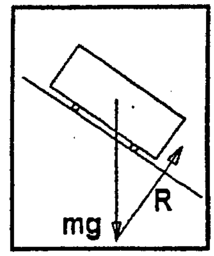

Figure 3

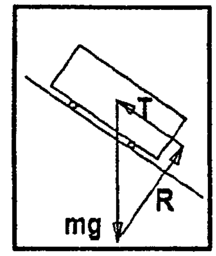

Figure 4

It becomes apparent that as the slope angle increases, that the force vector **T** becomes larger, to the point where **T** and **mg** are the same when the angle is 90° (free-hang). Conversely, the tension **T** becomes nil when the angle of the slope is 0° (level).

Simple guidelines can now be developed for a 10:1 SSSF by comparing the knotted breaking strength of your rope to the resultant tension or **T** in mainline for changing levels of mass and/or slope angle. Table 1 shows the resultant force for given slope angles (in degrees) and different sized rescue loads (kg). The non-shaded areas in the table represent acceptable levels of mainline tension (kN) for a 10:1 SSSF using an 11.1 millimetre (mm) or larger nylon kernmantle low-stretch rope, assuming a knotted breaking strength of at least 22 kN[1]. The lightly shaded region shows acceptable combinations of mass and slope angle for a 12.7 mm mainline, assuming a knotted breaking strength of approximately 33 kN. Force levels that exceed 10:1 SSSF for both 11.1 mm and 12.7 mm mainline ropes are shown in the darkest regions of the table. As an example, three litter bearers and a patient (i.e., 4 people with a combined mass of 400 kg), can maintain a 10:1 SSSF on slopes to just under 35° using an 11.1 mm mainline. If instead, they are using a 12.7 mm mainline, then the maximum slope angle can be increased (as expected) to just over 55°.

Table 1: Resultant Force (kN) for a given Slope Angle and Mass

Angle (°)	Mass (kg)				
	200 kg (2 people)	300 kg (3 people)	400 kg (4 people)	500 kg (5 people)	600 kg (6 people)
0°	0	0.00	0.00	0.00	0.00
5°	0.17	0.26	0.34	0.43	0.51
10°	0.34	0.51	0.68	0.85	1.02
15°	0.51	0.76	1.02	1.27	1.52
20°	0.67	1.01	1.34	1.68	2.01
25°	0.83	1.24	1.66	2.07	2.49
30°	0.98	1.47	1.96	2.45	2.94
35°	1.12	1.69	2.25	2.81	3.37
40°	1.26	1.89	2.52	3.15	3.78
45°	1.39	2.08	2.77	3.47	4.16
50°	1.50	2.25	3.00	3.76	4.51
55°	1.61	2.41	3.21	4.02	4.82
60°	1.70	2.55	3.40	4.25	5.10
65°	1.78	2.67	3.55	4.44	5.33
70°	1.84	2.76	3.69	4.61	5.53
75°	1.89	2.84	3.79	4.74	5.68
80°	1.93	2.90	3.86	4.83	5.79
85°	1.95	2.93	3.91	4.88	5.86
90°	1.96	2.94	3.92	4.90	5.88

[1] PMI Catalog #112, Page 5 states that "...our (11.1 mm) rope breaks at just over (22.2 kN) on a bowline knot."