Are Scrub Oak Shrubs a Viable Anchor Source for Rescue Sized Loads?

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Background

On May 6th, 2012 at 1848 hours West Metro Fire Rescue dispatchers received a 911 call for a male in his 20's that had fallen while free climbing approximately 30 feet onto a ledge. The incident occurred on the "hogback" of a popular recreational area in the southwest area of the Metro Denver area. Access was gained to the subject by hiking from a trailhead only ½ mile up to where the victim was located. Terrain was generally rough with abundant and overgrown scrub oak with an upward slope of approximately 40 degrees to the base of a 50 foot vertical ledge where the subject was located. Subject was found conscious and stable and complaining of upper and lower extremity injuries. The weather turned from a calm sunny day to persistent rain and temperatures dropping to 35 degrees as night fall set in. The subject was unprepared for the weather and quickly became cold and wet.

As rescue crews responded to the scene and gained access to the location of the victim a plan was quickly formulated to evacuate the subject and transport via ground (due to low ceiling air transport was ruled out). Due to the varying terrain transitions from high angle to low angle and overgrown vegetation a guiding line system was chosen to be employed. The selection of anchors of the top station was extremely limited and eventually a very large, approximately 36" scrub oak, was chosen as the guiding line anchor point. A 420 meter (700 foot) 11mm PMI Talon lifeline was tied to the scrub oak with a high strength tie-off using five wraps around the shrub. The HSTO was then back-tied to a juniper tree approximately 6 meters away using a pre-tension back tie and 8mm cordage. Main and belay systems were simultaneously rigged to independent anchors. Once all rigging was complete and the victim was packaged in a litter and attached to the system the Safety Officer conducted the West Metro standard operating procedure ABCDE system safety check (Anchors, Belay, Carabiners, Descent Control Device, and Edge protection/Edge positioning lines).

The victim and an attendant performed an edge transition down a 50 foot vertical face, and then transitioned to a 40 degree slope covered with thick scrub oak. Other fire crews onscene were assigned to cutting a path through the scrub oak with a chainsaw which proved to be somewhat helpful for the attendant to walk alongside of the litter instead of adding mass to the system. As the victim and attendant package approached mid slope of the evacuation there was a small tree that required a lateral deflection and the attendant to ride on the system to overcome. As the weather continued to change for the worse, a persistent rain continued to hamper rescuer footing. As the attendant deflected the guiding line, the HSTO for the guiding line suddenly constricted around the scrub oak anchor. This caused an audible whoosh and introduced about a 6" drop of the victim-rescuer package. An all-stop was called and all systems were evaluated. The scrub oak anchor was found with the 11mm HSTO still intact with considerable constriction of the bush from the original size. The exterior perimeter small branches had been sheared, but the root system had no signs of displacement. The back-tie to the juniper tree had indeed been loaded and no outward signs of stress or failure noted.

An after action report and lessons learned document was completed by West Metro. One area identified as needing to be addressed is further knowledge of anchor strength and viability of using vegetation anchors commonly encountered in our District for rescue operations and loads (Pfannenstiel, 2012). It is common for West Metro to encounter rescue situations in the wilderness environment devoid of sizable natural anchors as our terrain is in transition between the foothills to the plains of the Greater Denver Metro area (N. Jester, 2012). West Metro has utilized scrub oaks, juniper trees, and rock protection anchors in both rescue situations and trainings with success and without incident in the past. Due to the direction of the after action report of this incident, a plan was developed and implemented to conduct a series of tests of scrub oak anchors in the district to determine the feasibility of utilizing scrub oak shrubs as anchors in a rescue system.

Purpose

To derive enough test data to provide recommendations and best practices for viability on using a relatively small, scrub oak anchor in a rescue environment. The anchor shall be capable of holding a two person (2kN) load, with a safety factor appropriate for the risk and consequence given the rescue environment.

Gambel (Scrub) Oak

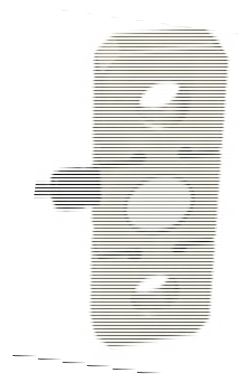
Gambel oak (*Quercus gambelii*), which is often referred to as scrub oak, is commonly found throughout western Colorado between 6,000 and 9,000 feet in elevation, generally dominates the region between the lower piñon-juniper zone and the aspen or ponderosa pine zone. Scrub oak often grow in stands, or thickets sometimes so thick they become impenetrable to wildlife which often feed on the acorns of the oak. Scrub oak is notoriously difficult to eradicate, especially in fire management zones to lessen the impact of wildfire around structures. Even after mechanical or prescribed fire removal of scrub oak, persistent growth is known to reoccur. The scrub oak can be found as large as twenty foot, almost a small tree format, however, they are most commonly found in abundance along the Front Range of Denver in stands around 3’ high.

Gambel oak flourishes in full sun on hillsides with thin, rocky, alkaline soil where competition from other plant species is limited. It also does well in richer soils, but in those areas it is forced to compete for growing room (Wikipedia, 2012). The plant reproduces from acorns, but spreads most rapidly from root sprouts that grow from vast underground structures called lignotubers. These reproductive characteristics often result in dense groves or thickets of the trees that often cover entire mountainsides.

Test Equipment

Prior to conducting field tests the equipment needed for the tests were gathered and included:

- [1]Dillon ED JR 5,000 rating dynometer
- [2]5,000 KG alloy steel construction tension link load cell with handheld display
- [3]TNT Rescue R-50 high pressure hydraulic ram
    - 10,500 psi operating pressure
    - 17,900 lb (79.6 kN) pulling force
    - 30” of ram extension/retraction
- [4]TNT Rescue SLR-40 high pressure hydraulic ram
    - 10,500 psi operating pressure
    - 8,115 lb (36 kN) pulling force
    - 24” of ram extension/retraction
- TNT Rescue BT 3.0 hydraulic rescue pump
    - 10,500 psi operating pressure
    - 98cc displacement engine
- [5]7,000 lb come-a-long
- ½” chain
- PMI 1” flat webbing
    - MBS:27 kN (6000 lbf)
- PMI 8mm accessory cord
    - MBS: 13.4 kN (3012 lbf)



[1] Used for the July 24th testing
[2] Used for the September 18th testing
[3] Used for the July 24th testing
[4] Used for the September 18th testing
[5] Come-a-long was not used for the July 24th testing

Test Method

Tests were conducted at two different test sites that had similar terrain features, scrub oak size, and soil type found within the district. All test scrub oak where anchored at the base of the shrub, incorporating the entire mass of the shrub using a wrap two- pull (W2P1) one anchor with 1" flat PMI webbing. The anchor was then connected to a chain or come-a-long, then to the hydraulic ram. The ram was

connected to the load cell or ED JR dynometer then the entire system was pretensioned using the come-a-long to 1kN on a single point pull and 3kN on all multi-point pulls[6]. The shrubs were pulled until there was root failure or until the shrub reached a 15° angle to prevent a slippage effect of the anchor webbing (note- this criteria was fairly subjective after visualizing the angle of the shrub and starting to see some upward slippage of the webbing).

Test Series #1

A series of test were conducted on July 24th, 2012 at the "Red Rocks Elementary Ridge" in Morrison, Colorado. It was noted that the Denver Metro Area had experienced records for the number of back to back days of 90 degree+ temperatures in July, 2012 and on the test day all he test shrubs were noted to be "the driest we had seen them". Soil conditions are relatively dry, sandy/pebbly soil that is fairly uncohesive. Following is the data collected from test series #1:

Single Point Anchors

Test #	Base Diameter	Max branch diameter	Anchor	kN	Comment
1	8"	1/2"	W2P1	2.6	Root displacement; pulled to >15˚
2	9"	1/2"	W2P1	1.4	Root displacement; pulled to >15˚
3	12"	1/2"	W2P1	7.4	Outer branch breakage; pulled <15˚
4	10"	1/2"	W2P1	3.2	Root displacement; pulled to >15˚
	10"	1/2"	W2P1	4.0	Outer branch breakage; pulled <15˚
5	10"	1/2"	W2P1	4.5	Outer branch breakage; pulled <15˚
6	10"	1"	W2P1	4.8	Outer branch breakage; pulled <15˚
7	12"	5/8"	W2P1	4.1	Outer branch breakage; pulled <15˚

[6] On 7/24 the come-a-long was not used and pretension was conducted with a 2:1 MA

8	9"	1/2"	W2P1	3.1	Root displacement; pulled to >15˚
9	12"	3/4"	W2P1	7.8	Outer branch breakage; pulled <15˚; max extension of ram
10	12"	1"	W2P1	5.8	Outer branch breakage; pulled <15˚

Multi-Point Anchors

Test #	Base Diameter	Max branch diameter	Anchor	Peak kN	Comment
1.1	13"	5/8"	W2P1	8.8	Test stopped due to > 15˚ displacement
1.2	12"	1/2"	W2P1	8.8	Test stopped due to > 15˚ displacement
2.1	10"	1/2"	W2P1	8.1	Soil starting to fracture ; outer branch breakage; pulled <15˚
2.2	12"	5/8"	W2P1	8.1	Soil starting to fracture ; outer branch breakage; pulled <15˚
3.1	10"	5/8"	W2P1	12.6	Soil starting to fracture ; outer branch breakage; pulled <15˚
3.2	10"	1/2"	W2P1	12.6	Soil starting to fracture ; outer branch breakage; pulled <15˚
3.3	8"	5/8"	W2P1	12.6	Soil starting to fracture ; outer branch breakage; pulled <15˚
4.1	10"	5/8"	W2P1	14.9	Outer branch breakage; no root displacement; test stopped due to max extension
4.2	10"	5/8"	W2P1	14.9	Outer branch breakage; no root displacement; test stopped due to max extension
4.3	12"	3/4"	W2P1	14.9	Outer branch breakage; no root displacement; test stopped due to max extension;
4.4	12"	5/8"	W2P1	14.9	Outer branch breakage; no root displacement; test stopped due to max extension;

Example: Test 2.1 and 2.2 are a two point anchor system. 3.1, 3.2, 3.3 is a three point anchor system.

Test Series #2

The second test series were conducted on September 18th, 2012 at Red Rocks Amphitheater Park in Morrison, CO. In contrast to the July test series, the weather had been more seasonably mild and we received about an hour of rain showers the day prior. Even with the rain, the soil was found to be dry, sandy/pebbly and still uncohesive. The following is the test data from the second test series:

Single Point Anchors

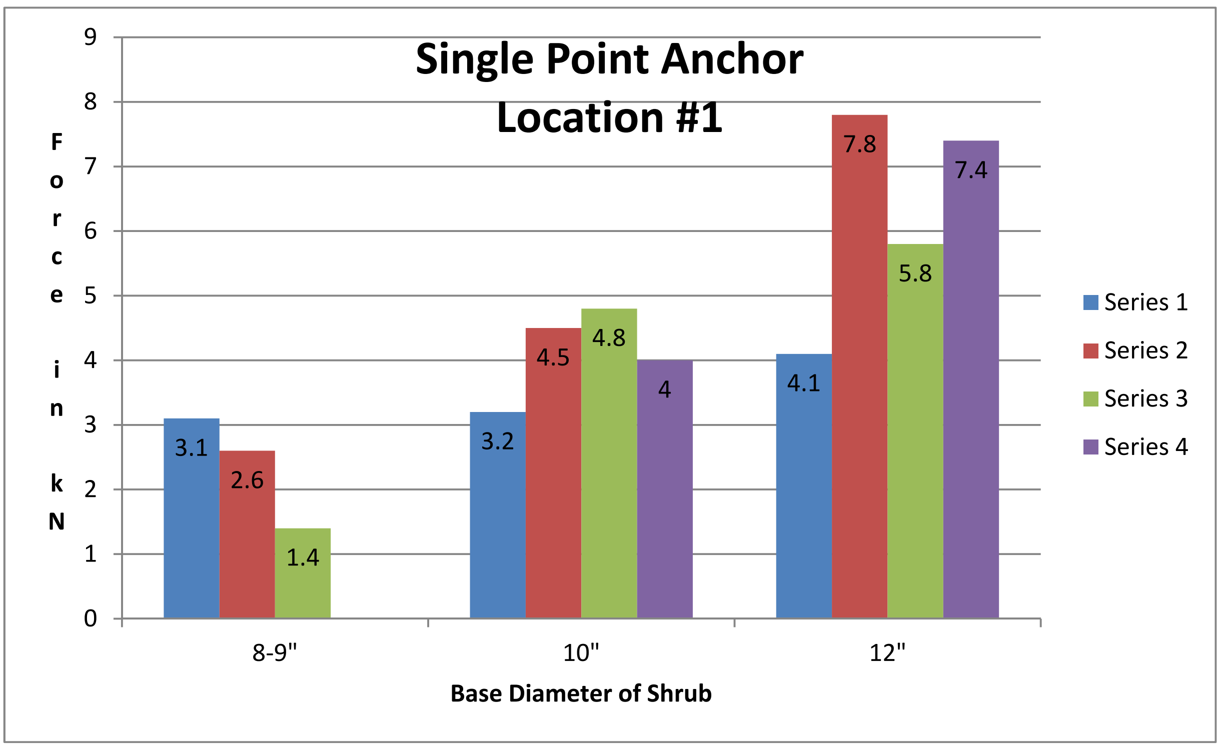
Test #	Base Diameter	Max branch diameter	Anchor	kN	Comment
1	8"	1"	W2P1	3.0	Root displacement; pulled to >15˚
2	8"	5/8"	W2P1	1.9	Root displacement; pulled to <15˚
3	8"	5/8"	W2P1	3.0	Root displacement; pulled to >15˚
4	14"	1"	W2P1	14.6	*previously used in a 4-MPA; oriented to a 10 ˚opposite slope angle; outer branch breakage; 3 resets

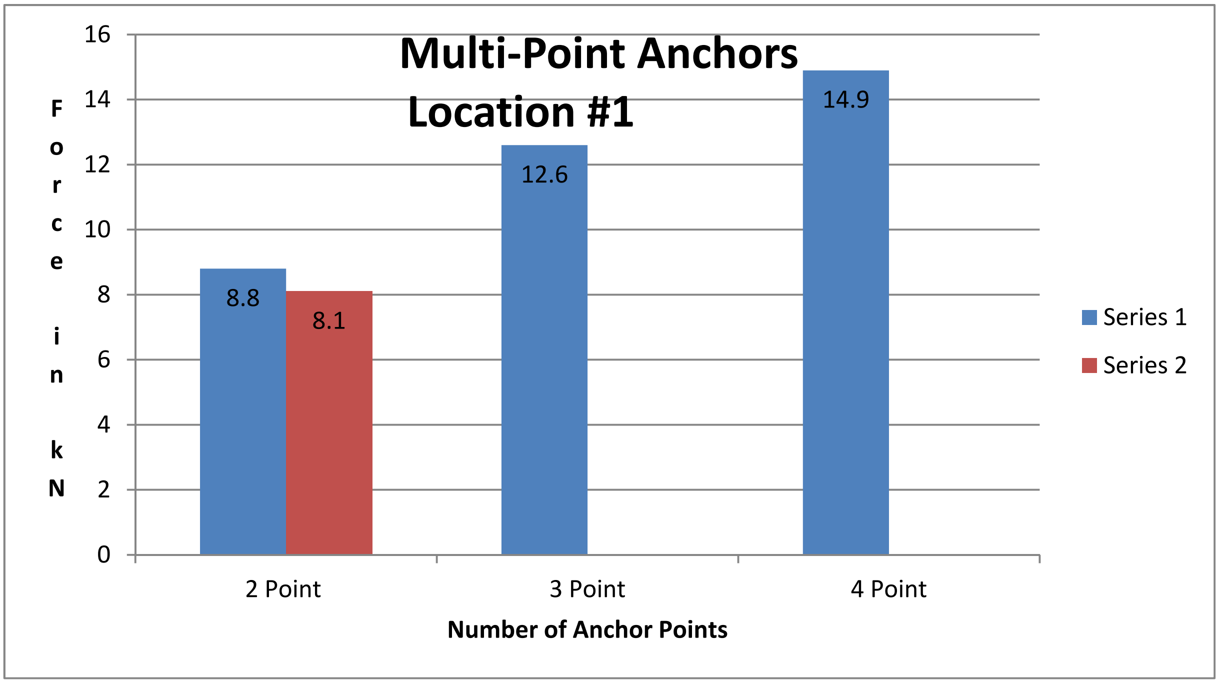
Multi-Point Anchors

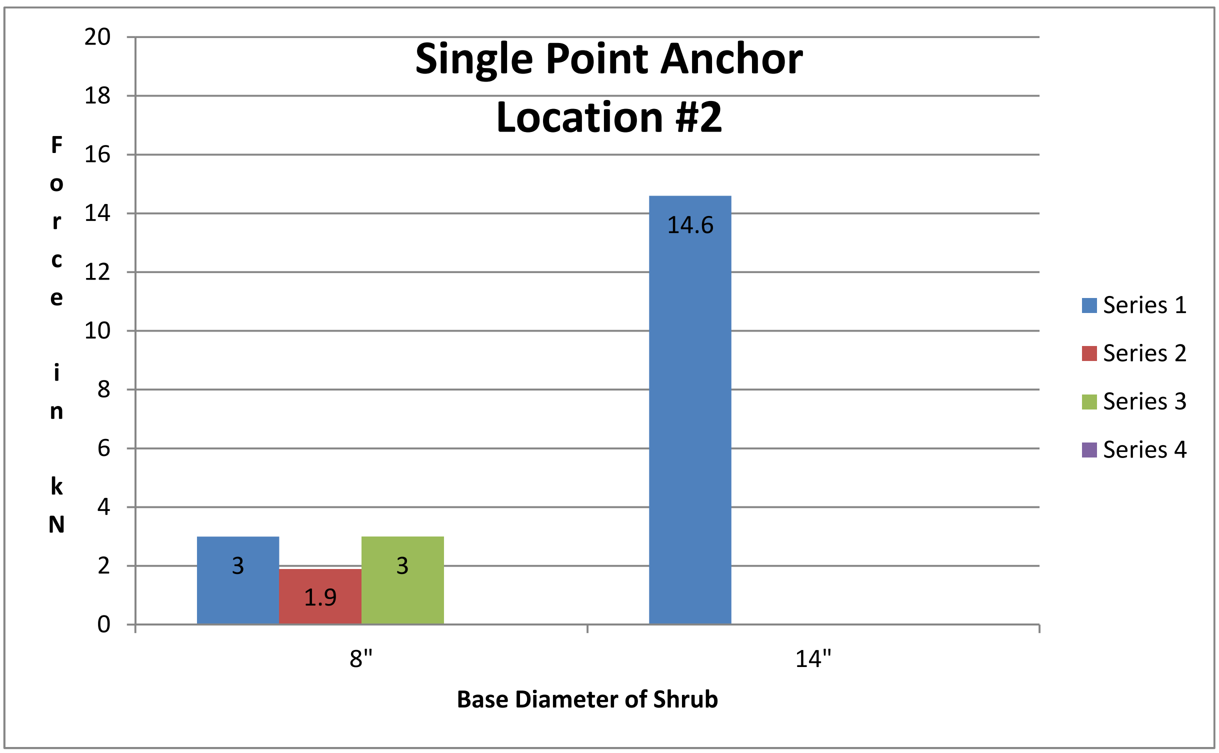
Test #	Base Diameter	Max branch diameter	Anchor	kN	Comment
1.1	10"	3/4"	W2P1	3.92	root displacement short leg
1.2	14"	1.5"	W2P1	3.92	open mass of shrub, large caliper
2.1	16"	3/4"	W2P1	6.26	root displacement short leg; reset 1 time
2.2	18"	1"	W2P1	6.26	root displacement short leg; reset 1 time
3.1	16"	3/4"	W2P1	7.85	root displacement short leg; pulled to >15˚
3.2	18"	1"	W2P1	7.85	root displacement short leg; pulled to >15˚
3.3	14"	1.5"	W2P1	7.85	root displacement short leg; pulled to >15˚
4.1	12"	3/4"	W2P1	4.7	root displacement short leg, smallest mass; 10˚ slope towards load
4.2	8"	1/2"	W2P1	4.7	root displacement short leg, smallest mass; 10˚ slope towards load
4.3	10"	5/8"	W2P1	4.7	root displacement short leg, smallest mass; 10˚ slope towards load
5.1	12"	3/4"	W2P1	4.64	2 anchors reused from test 4; 90˚ outside angle; root displacement R outside leg
5.2	10"	1/2"	W2P1	4.64	3 anchors reused from test 4; 90˚ outside angle; root displacement R outside leg
5.3	14"	1"	W2P1	4.64	4 anchors reused from test 4; 90˚ outside angle; root displacement R outside leg
6.1	16"	1.5"	W2P1	8.44	short leg middle root displacement
6.2	14"	1.5"	W2P1	8.44	short leg middle root displacement
6.3	12"	1"	W2P1	8.44	short leg middle root displacement
7.1	16"	1.5"	W2P1	6.94	smallest, short leg failed at 3kN pre-tension; root displacement L outside leg
7.2	14"	1.5"	W2P1	6.94	smallest, short leg failed at 3kN pre-tension; root displacement L outside leg

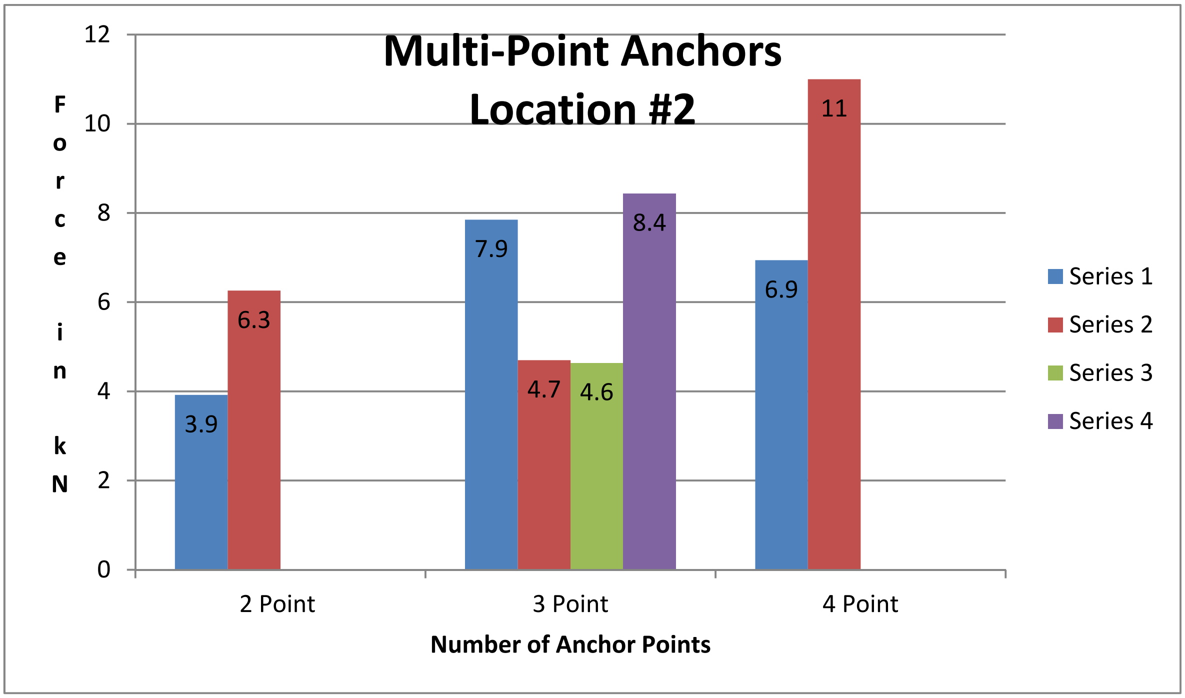
7.3	8"	5/8"	W2P1	6.94	smallest, short leg failed at 3kN pre-tension; root displacement L outside leg
7.4	12"	1"	W2P1	6.94	smallest, short leg failed at 3kN pre-tension; root displacement L outside leg
8.1	8"	1"	W2P1	11	root displacement of 10" mass; reset 2 times
8.2	10"	5/8"	W2P1	11	root displacement of 10" mass; reset 2 times
8.3	14"	1"	W2P1	11	root displacement of 10" mass; reset 2 times
8.4	10"	1"	W2P1	11	root displacement of 10" mass; reset 2 times

Anchor Strength Table View

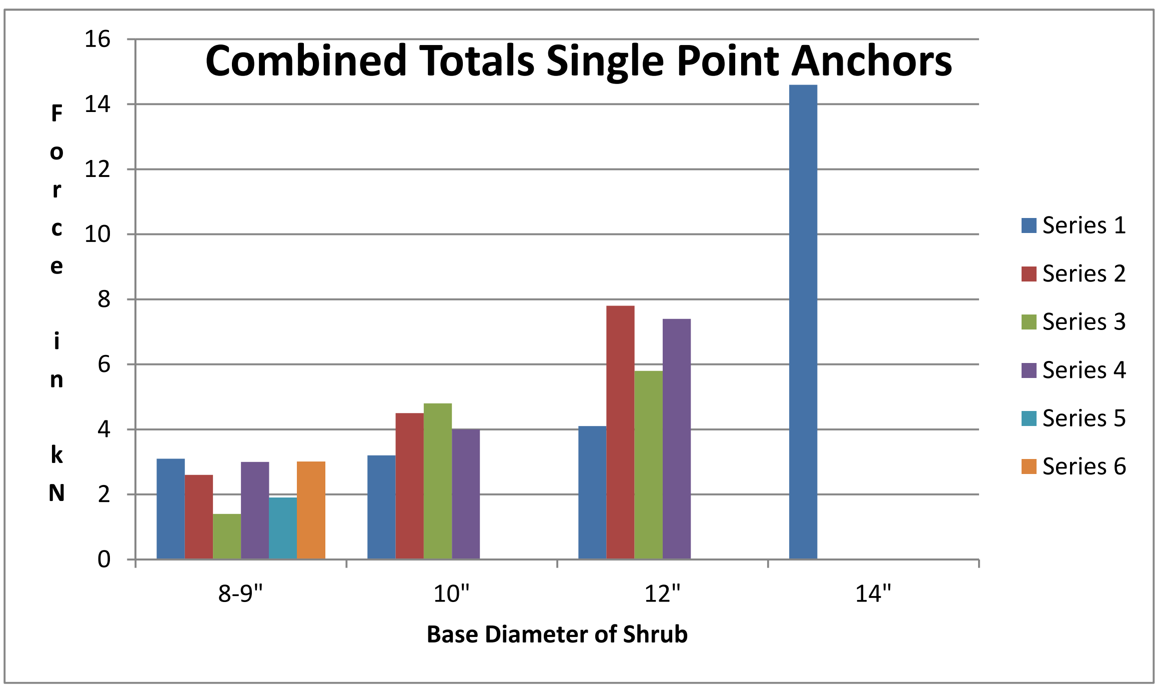


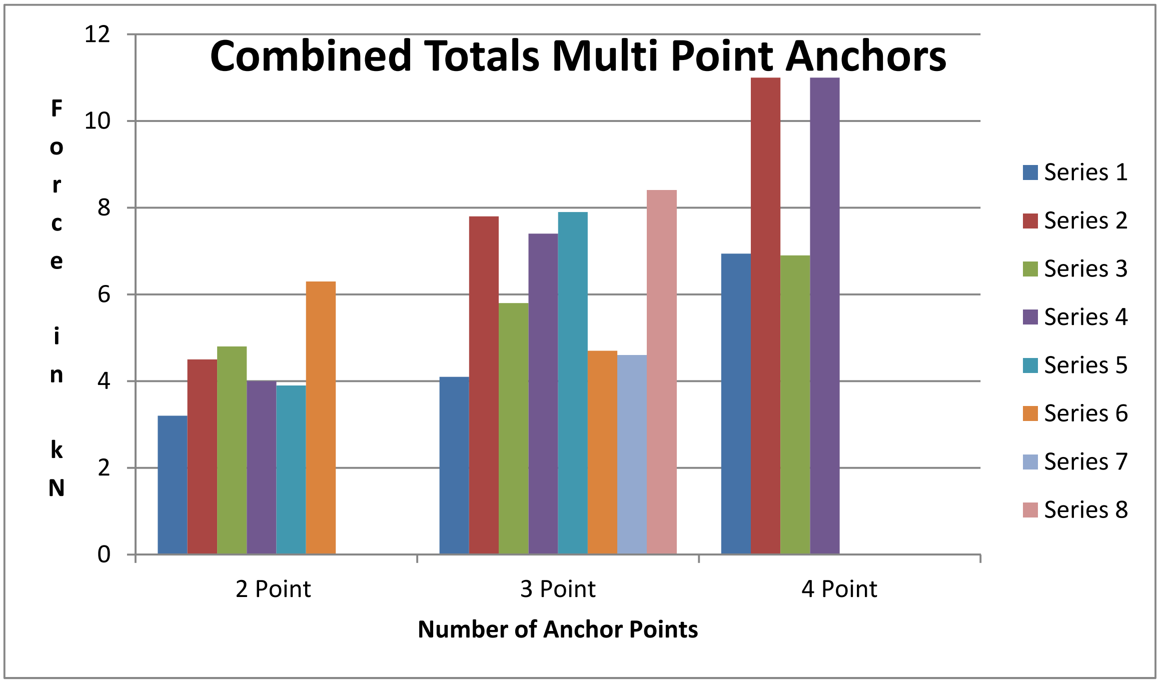

Multi-Point Anchors
Location #1
Force in kN
16
14
12
10
8
6
4
2
0
8.8
8.1
12.6
14.9
2 Point
3 Point
4 Point
Number of Anchor Points
Series 1
Series 2


Single Point Anchor
Location #2
Force in kN
20
18
16
14
12
10
8
6
4
2
0
3
1.9
3
14.6
8"
14"
Base Diameter of Shrub
Series 1
Series 2
Series 3
Series 4



Combined Graph View of all Tests





Take Away Points

Although it is difficult to derive a firm recommendation from testing natural vegetation that will have different strength characteristics depending on weather, time of year, soil type and condition, shrub size and health, there are several best practices to consider if facing the need to use scrub oak shrubs as rescue anchor:

1. Anchor Selection
    a. Only the largest and healthiest scrub oaks should be selected
    b. Shrubs smaller than 10” are not recommended to be used; *the cross section of a typical rescue helmet is 8”
    c. Ideally, scrub oaks should be part of an overall anchor system that includes several anchor points, which might include other anchoring techniques such as rock pro or other vegetation.
    d. A scrub oak anchor system may not be strong enough to resist the dynamic forces of a main failure when the mass arresting force (MAF) could reach 15kN. A separate, more substantial belay anchor may be appropriate.

2. Anchor Construction
    a. The amount of scrub oak anchor points to include in an anchor system will vary on size and condition of scrub oak, moderate size shrubs may require 4 or more points to achieve desired strength.
    b. W2P1 1" webbing placed at the soil level is adequate for the individual anchor points.
    c. A high-strength tie off should be avoided as it will not constrict as well as a W2P1.
    d. Individual scrub oak anchor points should be grouped close together to keep an outside angle of the shared multi-point anchor system within 90° as much as possible.
3. Pre Loading the Anchor System
    a. The shortest leg of the multi-point anchor system tends to see a proportionally higher load than the other anchor points.
    b. Constrict shrub down after tying with webbing to reduce movement when loaded.
    c. "Tug" on anchor system to further constrict and "test" the system.
    d. Pre-tension front tie is recommended to further constrict and load all anchor points.

Summary

The genesis for the test series was the use of a large scrub oak on a rescue incident for a portion of a guideline anchor. Two separate test series were conducted at separate locations in Morrison, CO. The first was conducted in July 2012 when the weather was noted to be hot and dry for an extended time. The second test was conducted in September 2012, when temperatures where more mild. The locations were typical of our rescue environment in our response district and anchors were selected based on health, size, and grouping. The series of tests produced a range of force values that did not readily identify a statistical average value of anchor strength. This was certainly anticipated when dealing with the subjective nature given with this type of natural anchor. However, when used as a part of a whole anchor system, scrub oak anchors could be considered when there are no other anchor means available to support a rescue sized load. It is also important to note that an anchor system comprised solely of scrub oaks may not be robust enough to withstand a worst case scenario mass arresting force. Users should evaluate their own response environment and conduct a risk-benefit analysis when deciding to use various types of natural anchors and anchoring techniques.

The author would like to thank the following individuals for their support and direction with this testing process:

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