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Hollister Hills SVRA

Trail Erosion Surveys

Summer 2016

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Executive Summary

As the number of off-highway vehicle users increases, more demand is placed on trails designated for off-highway vehicle use, and effective conservation efforts are necessary to maintain trail sustainability. Resource managers in Hollister Hills State Vehicular Recreation Area (SVRA), one of California's eight SVRAs where off-road driving is encouraged and managed, are developing a method for prioritizing trails for best management practice treatments. A 2012 report prioritized trail condition and sustainability based upon a three-level visual assessment and professional judgment. In collaboration with the park's environmental scientists, a representative subset of those trails (18 sites) was selected for more detailed work aimed at quantifying trail erosion through time serial surveys. The sample sites were selected to include variability in trail use: road, all-terrain vehicle (ATV), and single-track; soil: clay and granitic; and trail sustainability: green, yellow, and red. In 2013 a baseline assessment and digital elevation model was created for each site using ArcGIS. In 2015 survey technology changed from a robotic total station to structure from motion, low-altitude photogrammetry to increase survey extent. The present report details data from June of 2016 when the sites were resurveyed using the same protocol as the 2015 surveys. Changes in the elevation of sites were compared by raster subtraction in ArcGIS. Unlike previous reports, the elevation changes are reported as negative to signify a decrease in elevation (erosion) and positive to indicate an increase in elevation (deposition). El Niño conditions occurred between 2015 – 2016, making it the highest precipitation year since the start of the study in 2007. Previous observations were set in the context of drought.

The overall results, averaged for all years of the study, indicate that the three level trail assessment used at Hollister Hills accurately identifies trails with three different levels of erosion. The study indicates that trails on granite soils erode faster than those on clay soils, perhaps because of seasonal restrictions in utilization. Lastly, higher erosion rates are linked to higher annual precipitation.

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1 Introduction

1.1 Background

In 2012 Hollister Hills State Recreational Vehicle Area (SVRA) resource managers created an index to rate the erodibility of the trails: green (acceptable), yellow (marginal), and red (action needed). The rating index was based on a visual assessment of the road's physical context and condition (HHSVRA 2012).

This report is the fourth in a series of publications that is calibrating the rating system based upon annual resurveys of a select sample of the trails. The study includes 18 sites across the SVRA to account for geologic substrate (Granitic and Clay), vehicle use types (Single Track, ATV, and Road), and trail erodibility index (Green, Yellow and Red). The first trail surveys were conducted in 2013 (Teaby et al. 2013). Trail erosion has been annually assessed each year since the 2013 baseline survey (Silveus et al 2014; Chow et al. 2015). This report provides the findings of trail evolution after three years.

1.2 Study Area

Hollister Hills SVRA is located between the city of Salinas and Hollister (Figure 1). Established in 1975 the park boasts 6,640 acres of camping sites, hiking trails, and recreational vehicle trails among the Gabilan Mountains of San Benito County. Different riding options are available depending on the different properties within the park: Upper Ranch, Lower Ranch, and the Renz Property. The Upper Ranch contains 800 acres and approximately 24 miles of 4x4 (4-wheel drive) trails. The Lower Ranch is the largest property at 3,300 acres and 128 miles of dirt bike and ATV trails. The newest property, the Renz Property, opened in 2008 and contains 23 miles of ATV and motorcycle trails.

1.3 Goals

The long-term goal of this report series is to assess the 2012 trail ranking system by quantifying the volume of soil lost from the trails each year as a function of rainfall, trail parameters, and trail erodibility rating.

1.4 Photogrammetry

Photogrammetry is the process of taking overlapping aerial images to digitize landscapes. This process uses a specialized software based on multi-view stereo technology, such as Agisoft Photoscan (St. Petersburg, Russia), to create digital elevation models (DEMs). Ground control points (GCPs) are used to georeference and scale the DEM to a known location. They also allow reproducibility within a survey by using existing frameworks. Photogrammetry is regarded for being able to capture small changes in topography for a wider area without the time associated with traditional methods.

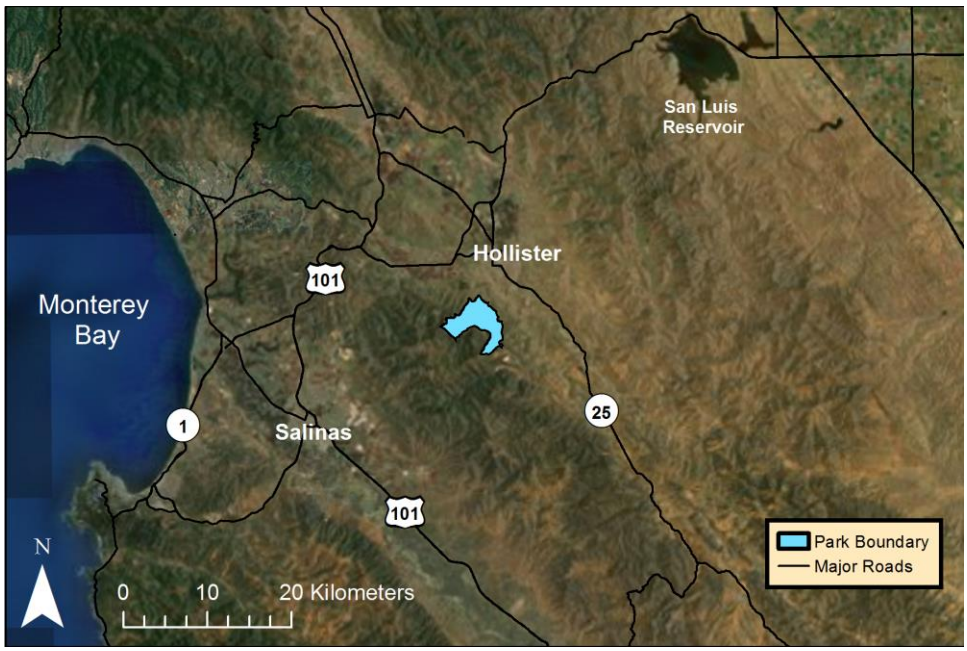

Figure 1. Hollister Hills State Vehicular Recreation Area is found northeast of Salinas.

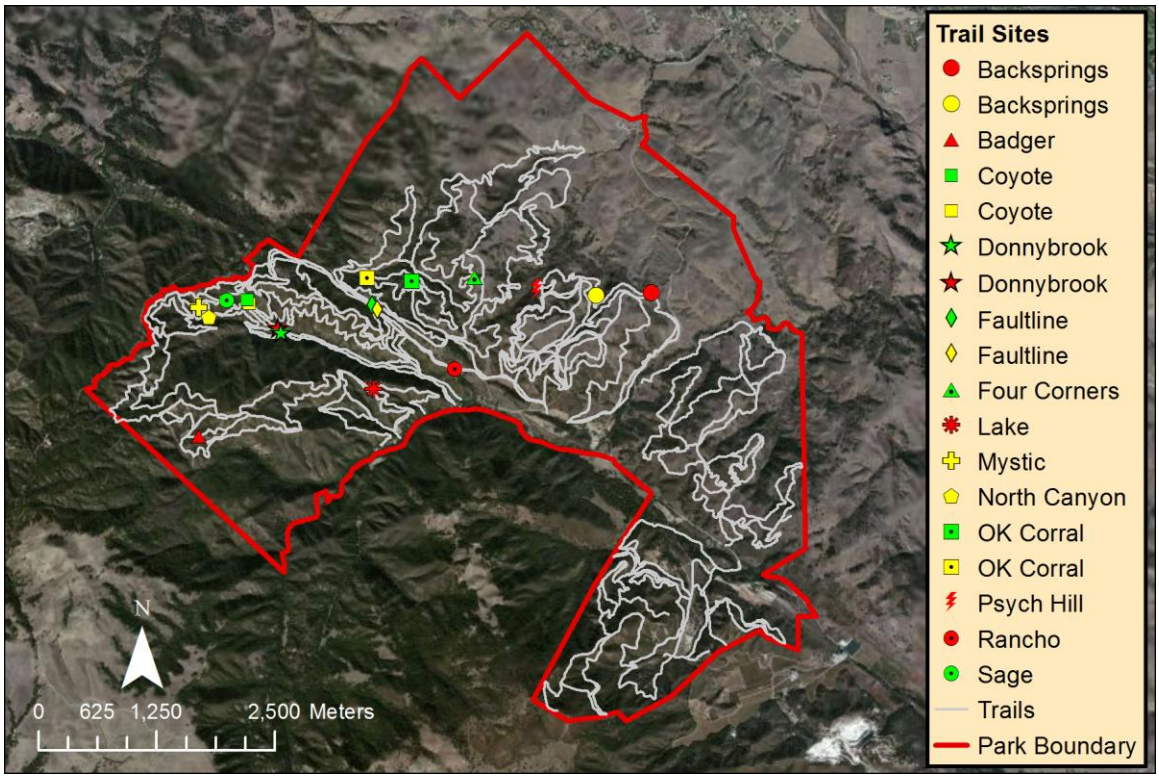

Figure 2. Trail site locations within Hollister Hills State Vehicular Recreation Area, Hollister, CA.

2 Methods

2.1 Field Survey

All 18 sites that were surveyed in 2013 were revisited and surveyed using the same, local framework by setting up a Nikon Total Station on a historic benchmark (BM) and establishing a local horizontal axial system on a backsight to a second benchmark.

At each site, the extent of the previous surveys was estimated to ensure that this year's surveys captured the same area. Within the survey footprint, 10 cm x 10 cm, plastic square ground control points (GCPs) were placed every 2 meters in a zigzag pattern throughout the trail and temporarily nailed in place with a spike. The local coordinate of each GCP was measured using a 3 arcsecond Nikon Total Station.

Aerial photos were captured with a Hero 3+ GoPro in a "mowing the lawn" pattern at different angles to ensure sufficient photo overlap and that each photo contained multiple GCPs. Altitude of each aerial photograph was approximately 3.9 meters.

2.2 Surface Modeling

For each site we selected over 20 photos that contained multiple GCPs, had a clear view of the trail from different locations, and minimal vegetation interference to upload into Agisoft Photoscan. Parameters were adjusted to account for the fisheye lens of the GoPro camera. Within the workflow of the software, photos were aligned and GCPs were manually placed for each site. Each GCP was optimized based on RMS error. A dense point cloud was created using mild depth filtering to retain as much surface microtopography as possible without encouraging spurious points. A DEM and orthophoto were exported for each site. Workflow for DEM creation using Agisoft is further elaborated in the Agisoft tutorial (Agisoft 2014). Table 1 summarizes a variety of parameters associated with each DEM, including trail use, substrate type, DEM inputs and resulting DEM resolution.

Table 1: Table showing the locations, usage, site condition, 2013 area, 2016 area and input parameters (number of photos, number of GCPs, and approximate flying altitude), as well as resulting resolution, root mean square error (RMSE), and point density for each site's DEM.

Trail Location	Usage	Condition	Soil Type	2016 area (m^2)	# photos	# GCPs	Altitude (m)	GCP RMSE (m)	Res. (m/pix)	Point Density (points/ m^2)
OK Corral	Single Track	Green	Clay	16.27	41	9	5.5	0.007	0.010	10,147
OK Corral	Single Track	Yellow	Clay	23.41	36	7	4.4	0.016	0.008	17,085
Psych Hill	Single Track	Red	Clay	58.27	47	12	2.3	0.007	0.004	50,810
Donnybrook	Single Track	Green	Granite	33.58	45	10	2.8	0.014	0.006	28,249
Mystic	Single Track	Yellow	Granite	19.28	48	11	2.1	0.019	0.009	13,730
Donnybrook	Single Track	Red	Granite	56.84	61	11	3.2	0.019	0.006	31,626
4 Corners	ATV	Green	Clay	98.81	45	10	3.7	0.023	0.007	20,211
Backsprings	ATV	Yellow	Clay	59.70	57	11	3.1	0.008	0.007	23,121
Backsprings	ATV	Red	Clay	180.20	41	8	7.3	0.011	0.010	10,827
Coyote	ATV	Green	Granite	26.89	46	10	2.7	0.021	0.006	31,855
Coyote	ATV	Yellow	Granite	44.16	52	13	2.7	0.018	0.006	29,968
Badger	ATV	Red	Granite	93.07	48	9	4.6	0.012	0.007	19,036
Faultline	Road	Green	Clay	80.85	46	11	5.3	0.012	0.009	13,446
Faultline	Road	Yellow	Clay	97.32	77	17	5.2	0.017	0.009	13,562
Rancho	Road	Red	Clay	137.89	50	11	4.5	0.017	0.008	15,257
Sage	Road	Green	Granite	37.84	41	10	4.0	0.012	0.007	19,704
North Canyon	Road	Yellow	Granite	118.23	62	11	4.1	0.013	0.008	15,710
Lake	Road	Red	Granite	94.52	68	12	3.9	0.012	0.005	18,194

2.3 Analysis

ArcMap (v. 10.1) was used to create a difference of DEMs (DODs) for every site by using *Raster Calculator* to subtract the 2016 DEM from the 2015, 2014 and 2013 DEMs. Due to the areal coverage difference of the 2016, 2015, and 2013 DEMs the DOD of every site is the extent of the smallest raster. We assumed that the BM did not move so rasters were shifted to match the 2013 elevations. A mask was created to exclude vegetation and specify the extent of analysis for each raster. The *Cut and Fill* tool was used to calculate area and volume of each site. Values were extracted out of ArcMap attribute tables. The 2016 elevations, areas, and volumes obtained from this process were compared with those of 2015, 2014, and 2013 values to quantify both annual and total change. Microsoft Excel was used to analyze and generate graphs of the data. Precipitation data were obtained from the Hollister Hills Weather Monitoring Station within the park boundary.

3 Results

Results are provided in the table below with regard to soil type, vehicle usage, and index classification (Tables 2 & 3, Figs 2 through7). “NA” denotes missing DEMs, or sites where differences resulted from trail maintenance rather than from vehicle use. The sites altered by trail maintenance are denoted by greyed boxes in Tables 2 and 3. Altered sites are not further analyzed.

Areas differ between years due to changing surveying technology from a robotic total station to photogrammetry (Table 2). This year a mask was implemented to further exclude vegetation and digital distortion in the product rasters.

Change in elevation values can be multiplied by the analysis area to approximate the volumetric change of sediment between years (Δ elevation $\times$ area = volume).

Table 2: Site specific location, usage, condition, soil type, change in elevation (m), standard deviation (m), area (m^2), and volume (m^3) for the total study time (2013 – 2016. Usage is divided into Single Track, ATV, and Road. Site condition is based on the index as green (acceptable), yellow (marginal), and red (action needed). Soil type is denoted by being either clay or Granitic. Sites with insufficient data are denoted by "N/A." Greyed out sections are sites that have been altered between 2015 and 2016 surveys. Positive numbers indicate deposition and negative numbers indicate erosion.

Trail Location	Usage	Condition	Soil Type	Total Change (2013-2016)			
				Δ Elev (m)	SD (m)	Area (m^2)	Vol (m^3)
OK Corral	Single Track	Green	Clay	-0.05	0.03	3.14	-0.16
OK Corral	Single Track	Yellow	Clay	-0.08	0.08	4.36	-0.35
Psych Hill	Single Track	Red	Clay	0.15	0.15	7.77	1.19
Donnybrook	Single Track	Green	Granite	-0.07	0.06	5.76	-0.37
Mystic	Single Track	Yellow	Granite	-0.02	0.06	2.58	-0.06
Donnybrook	Single Track	Red	Granite	-0.12	0.08	10.74	-1.32
4 Corners	ATV	Green	Clay	0.01	0.01	7.51	0.08
Backsprings	ATV	Yellow	Clay	0.16	0.18	13.47	2.19
Backsprings	ATV	Red	Clay	-0.12	0.03	8.89	-1.10
Coyote	ATV	Green	Granite	-0.02	0.02	4.16	-0.10
Coyote	ATV	Yellow	Granite	0.17	0.18	7.67	1.32
Badger	ATV	Red	Granite	-0.07	0.06	6.73	-0.49
Faultline	Road	Green	Clay	-0.05	0.02	10.45	-0.52
Faultline	Road	Yellow	Clay	-0.08	0.18	5.12	-0.39
Rancho	Road	Red	Clay	1.38	0.05	11.05	15.29
Sage	Road	Green	Granite	-0.02	0.08	8.40	-0.19
North Canyon	Road	Yellow	Granite	-0.10	0.03	7.57	-0.78
Lake	Road	Red	Granite	-0.18	0.04	9.31	-1.65

Table 3: Site specific location, usage, condition, soil type, change in elevation (m), standard deviation (m), area (m^2), and volume (m^3) for the subsequent annual years. Usage is divided into Single Track (S), ATV (A), and Road (R). Site condition is based on the index as green (acceptable – G), yellow (marginal – Y), and red (action needed – R). Soil type is denoted by being either clay (C) or Granitic (G). Sites with insufficient data are denoted by "N/A." Greyed out sections are sites that have been altered since previous surveys. Positive numbers indicate deposition and negative numbers indicate erosion.

Trail Location				Annual Change (2013-2014)				Annual Change (2014-2015)				Annual Change (2015-2016)			
	Usage	Condition	Soil	Δ Elev (m)	SD (m)	Area (m^2)	Vol (m^3)	Δ Elev (m)	SD (m)	Area (m^2)	Vol (m^3)	Δ Elev (m)	SD (m)	Area (m^2)	Vol (m^3)
OK Corral	S	G	C	-0.01	0.02	3.14	-0.03	0.00	0.03	3.14	0.00	-0.04	0.03	16.27	-0.61
OK Corral	S	Y	C	-0.02	0.03	4.14	-0.10	0.00	0.06	4.14	0.00	-0.08	0.10	17.27	-1.81
Psych Hill	S	R	C	N/A	N/A	5.14	N/A	N/A	N/A	5.14	N/A	0.12	0.13	18.27	7.10
Donnybrook	S	G	G	-0.04	0.05	6.14	-0.21	-0.04	0.02	6.14	-0.38	0.01	0.03	19.27	0.31
Mystic	S	Y	G	0.00	0.02	7.14	-0.01	-0.02	0.03	7.14	-0.04	-0.02	0.05	20.27	-0.37
Donnybrook	S	R	G	-0.04	0.05	8.14	-0.12	-0.06	0.06	8.14	-0.34	-0.17	0.23	21.27	-2.06
4 Corners	A	G	C	-0.01	0.00	9.14	-0.06	-0.08	0.01	9.14	-0.53	0.01	0.12	22.27	1.08
Backsprings	A	Y	C	-0.01	0.02	10.14	-0.17	-0.01	0.04	10.14	-0.15	0.07	0.17	23.27	4.10
Backsprings	A	R	C	-0.01	0.03	11.14	-0.05	0.00	0.07	11.14	-0.03	-0.17	0.23	24.27	-30.47
Coyote	A	G	G	-0.02	0.01	12.14	-0.10	0.00	0.01	12.14	-0.01	-0.03	0.14	25.27	-0.79
Coyote	A	Y	G	N/A	N/A	13.14	N/A	-0.03	0.03	13.14	-0.25	0.03	0.05	26.27	1.63
Badger	A	R	G	-0.04	0.03	14.14	-0.26	-0.04	0.03	14.14	-0.25	-0.17	0.23	27.27	-0.99
Faultline	R	G	C	-0.02	0.01	15.14	-0.20	-0.04	0.01	15.14	-0.46	-0.03	0.08	28.27	-1.98
Faultline	R	Y	C	-0.04	0.18	16.14	-0.23	-0.05	0.03	16.14	-0.16	-0.03	0.06	29.27	-2.87
Rancho	R	R	C	-0.02	0.03	17.14	-0.21	-0.03	0.10	17.14	-0.41	1.29	0.37	30.27	177.97
Sage	R	G	G	-0.01	0.01	18.14	-0.07	0.00	0.03	18.14	-0.01	-0.03	0.06	31.27	-0.84
North Canyon	R	Y	G	-0.06	0.01	19.14	-0.46	-0.02	0.02	19.14	-0.14	0.08	0.20	32.27	9.79
Lake	R	R	G	-0.08	0.03	20.14	-0.77	-0.04	0.03	20.14	-0.36	0.02	0.13	33.27	1.09

Most sites eroded less than 8 cm on average over the 2015-16 timeframe and less than 12 cm on average over the three-year span, regardless of trail type, substrate, or color rating (Figs 3 & 4). The 2015 – 2016 study year shows the highest variability in elevation change with 9 sites showing net erosion and 4 sites showing net aggradation. The highest average three-year erosion value was 12 cm on a red, granitic soil site. A yellow, granitic soil site showed the highest soil deposition at 17 cm within the three-year study period (Table 2). In both the annual change from 2015 to 2016 and the three-year change from 2013 to 2016, clay soils were less erosive than granitic soils in the red sites. From 2015 to 2016 and 2013 to 2016, clay soils were less stable than granitic soils in the yellow sites. There was no difference between the two soil types in the green sites between 2013 – 2016, but between 2015 – 2016 clay sites eroded more than granitic sites (Figs. 3 & 4).

Single Track trails appear to have larger elevation changes between green to red classification (Fig. 5). Regardless of substrate, elevation change was smallest at green sites, moderate at yellow, and largest at red classified sites throughout the three-year period. Based on the three ATV sites, yellow had the highest and only elevation change in the positive direction while the green site had the least and red had the most erosion over three years (Fig. 6). There were no red road sites included in the analysis because of trail maintenance this year, but from the remaining road sites green had less erosion than yellow classified trails (Fig. 7).

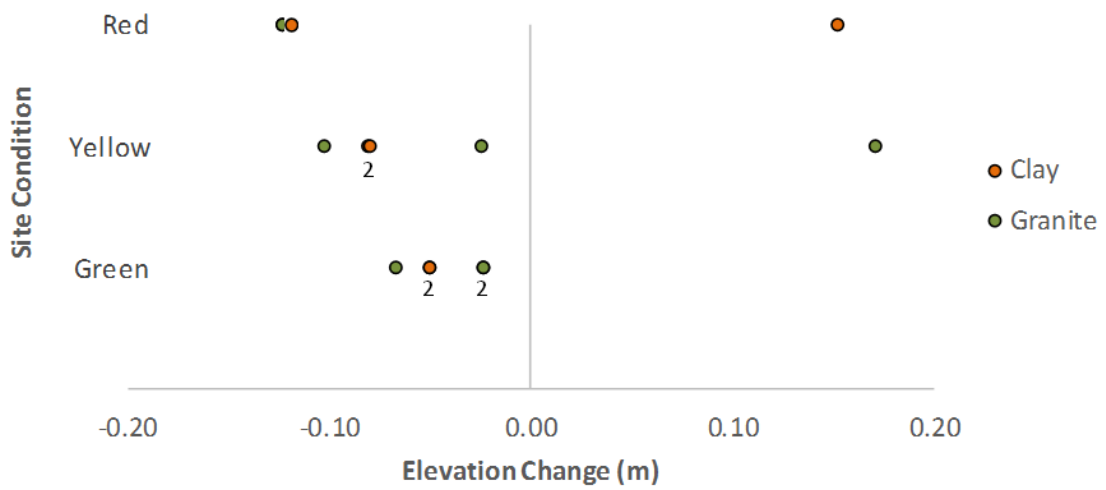

Figure 3: Total change in site elevations based on soil type and site condition for 2013 – 2016. Positive numbers indicate deposition and negative numbers indicate erosion. A "2" indicates the data point represents two sites with the same condition, substrate, and elevation change.

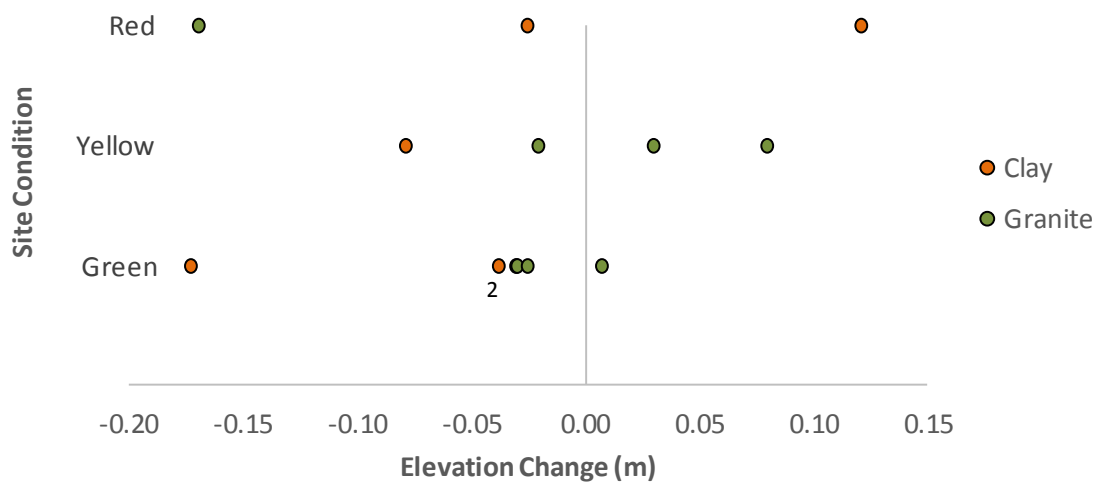

Figure 4: Annual change in site elevations based on soil type and site condition for 2015 – 2016. Positive numbers indicate deposition and negative numbers indicate erosion. A "2" indicates the data point represents two sites with the same condition, substrate, and elevation change.

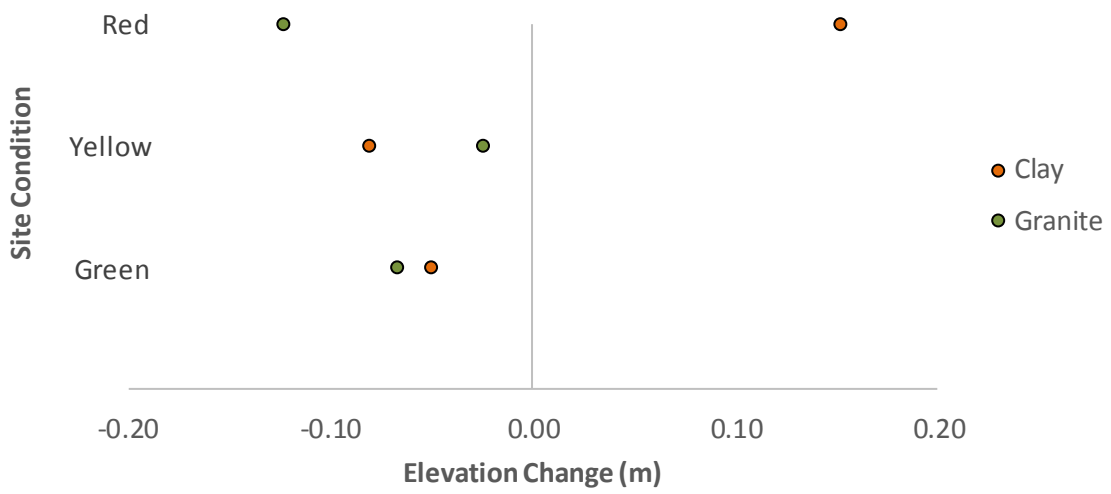

Figure 5: Total change in Single Track site elevations based on soil type and site condition for 2013 – 2016. Positive numbers indicate deposition and negative numbers indicate erosion.

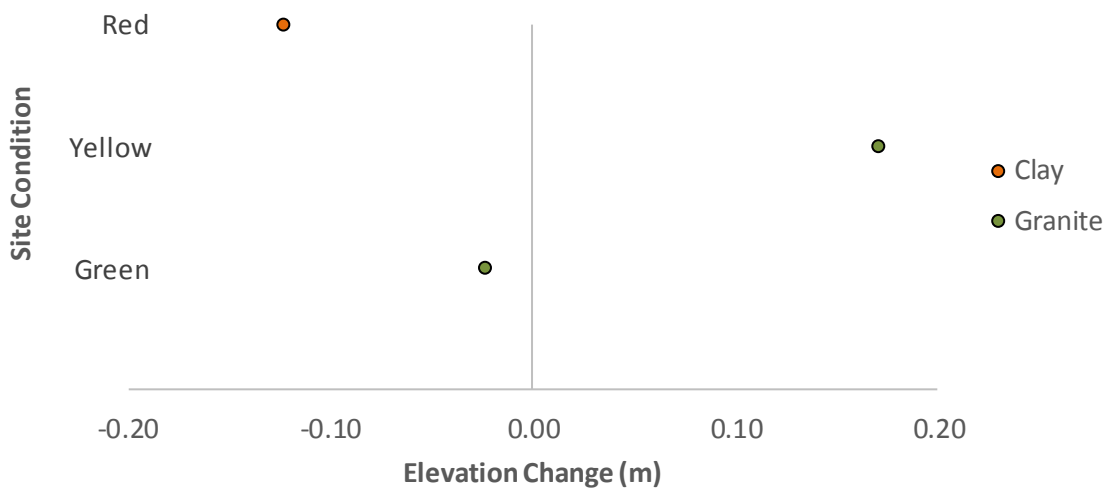

Figure 6: Total change in ATV site elevations based on soil type and site condition for 2013 – 2016. Positive numbers indicate deposition and negative numbers indicate erosion.

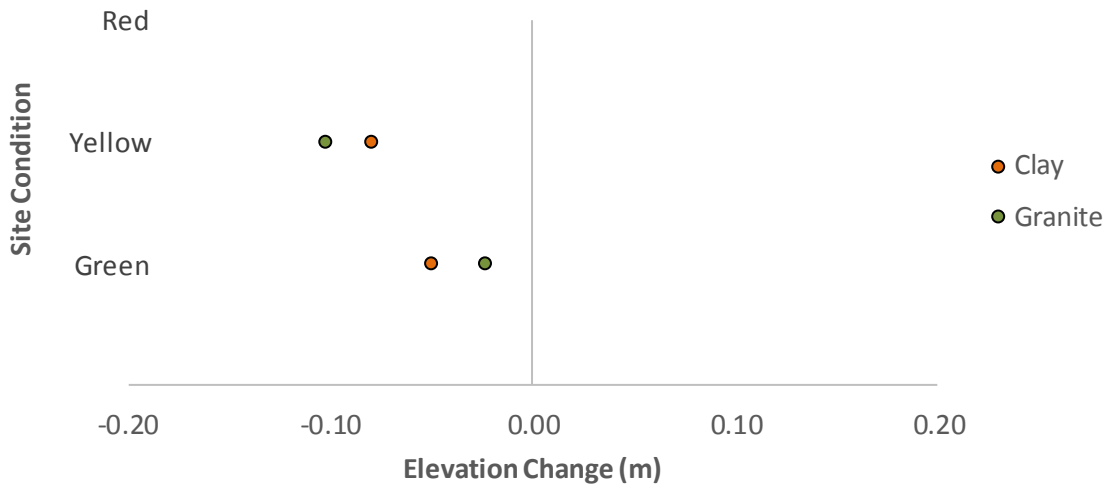

Figure 7: Total change in Road site elevations based on soil type and site condition for 2013 – 2016. Positive numbers indicate deposition and negative numbers indicate erosion.

Average annual elevation differences between site condition show red trails as having the highest average erosion with 2015–2016 having the highest erosion (Fig. 8). Yellow trails are variable, but generally have an average erosion rate of 0.02 m of elevation change in a single year. Green trails consistently have an average, annual erosion of 0.02 m as well.

In 2015–2016, clay and granitic trails had the largest amount of elevation change at –0.04 m and –0.05 m respectively (Fig. 9). Granitic trails seem to consistently erode more than clay trails. Based off these observations, red granitic trails might erode more than other trail types.

	Avg Elev Δ		
	Green	Yellow	Red
2013-2014	-0.02	-0.03	-0.02
2014-2015	-0.02	-0.02	-0.03
2015-2016	-0.02	-0.01	-0.10
2013-2016	-0.02	-0.02	-0.05

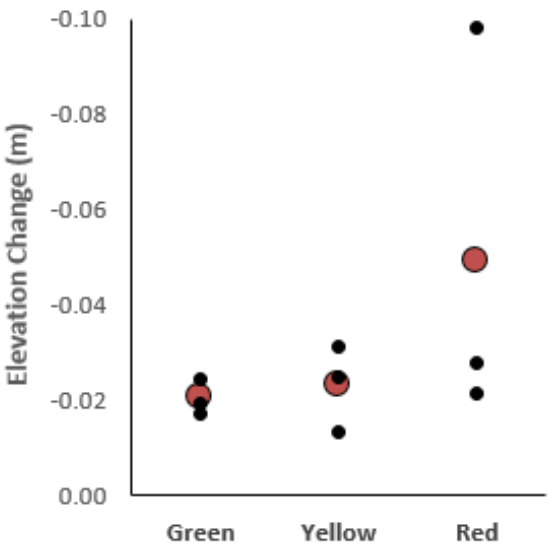

Figure 8. Average elevation change ("Avg Elev Δ," m) for each year separated by site condition. Black dots indicate annual average erosion. The larger, red dots indicate total average erosion between 2013–2016. Positive numbers indicate deposition and negative numbers indicate erosion.

	Avg Elev Δ	
	Clay	Granite
2013-2014	-0.02	-0.03
2014-2015	-0.02	-0.03
2015-2016	-0.04	-0.05
2013-2016	-0.02	-0.04

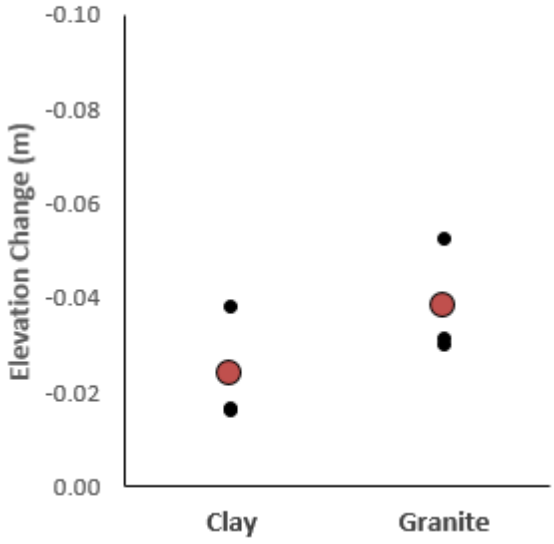

Figure 9. Average elevation change ("Avg Elev Δ," m) for each year separated by soil type. Black dots indicate annual average erosion. The larger, red dots indicate total average erosion between 2013–2016.Positive numbers indicate deposition and negative numbers indicate erosion.

Within the study period, the lowest amount of precipitation was observed between 2013 and 2014. A moderate amount of precipitation fell between 2014 – 2015. Precipitation between the 2015 – 2016 surveys was the highest at 19.51 inches (Table 4). Despite slight variation, at average annual erosion seems to occur where annual precipitation is also large.

Table 4: Annual precipitation (in and mm), average annual elevation change (mm) and total elevation change (mm). Precipitation data obtained for 2013 – 2014, 2014 – 2015, 2015 – 2016, and 2013 – 2016 from Western Weather Group.

	Precipitation (in)	(mm)	Δ Elevation (m)
Annual 2013-2014	5.91	150.1	-0.02
Annual 2014-2015	11.41	289.8	-0.02
Annual 2015-2016	19.51	495.6	-0.04
Total 2013-2016	36.83	935.5	-0.04

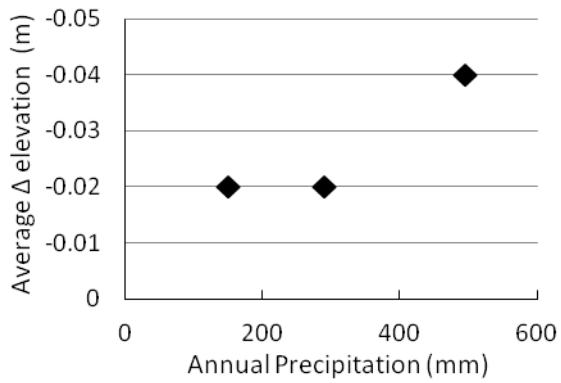

Figure 10: Graphical interpretation of annual precipitation vs. average annual change in elevation. Elevation change remained somewhat constant during lower precipitation years and increased with increased precipitation.

4 Discussion

The 2016 analysis areas are smaller than the 2015 analysis areas because a mask was used to exclude vegetation and to indicate trail width extent. However, current analysis extent is still far greater than the original surveys due to the newer photogrammetric methods.

This year we were unable to analyze a few sites due to trail management. Though trail management is good for erosion control and safety, it greatly reduces our sample size and overall ability to detect natural trends of erosion.

Between 2015 – 2016, elevation change was highly variable compared to previous years. Most sites displayed net erosion, but even after excluding manually altered sites, four sites displayed possible soil aggradation (Tables 2 & 3). Psych Hill and Donnybrook are steeper trails indexed as red – management needed. Both sites display higher soil accumulation rates due steeper slopes causing uphill erosion and downhill soil deposition. Local topography also contributes to local erosion and deposition trends. The Donnybrook sites in particular are located at the base of a failing gully restoration on Coyote Trail. Sediment deposited via runoff from this gully will settle out on Donnybrook trail, explaining why the Donnybrook sites display more soil deposition. At this time our data is too variable to confidently determine whether classification particularly of red sites was flawed.

Despite a large amount of variation overall and annually, and regardless of net soil gain or loss, granite trails display a fairly constant trend of green, yellow, and red sites having the smallest, moderate, largest annual elevation change respectively. Clay soil types show red, green, and yellow trails as having the least, moderate, and highest elevation change based on the past three years of data (Table 3). Between the two soil types, granitic trails appear to consistently erode more than clay trails while red classified sites erode more than yellow and green sites. From these observations, we infer that red classified, granitic trails might erode more than the other trail classes and types.

Some, if not all, variation might be explained by the large amount of precipitation that the area received in the past year. Previous studies were conducted in drought years where annual precipitation was below the average of 14.25 inch (Western Weather Group). This is the first El Niño year in this study period and additional, higher precipitation years are needed to determine erosion rates in the context of more rain.

Other sources of variation could be from unequal trail use thought the park. Not all trails are used as heavily as multi-vehicle, gateway trails such as Backsprings, Faultline, and Rancho while trails farther out and for limited vehicles are used less such as Badger and Donnybrook. Single Track trails are only wide enough for bikes, but roads can be accessed by any vehicle. Trail usage data could be used in future analyses to explore possible trends in trail use and stability.

5 Conclusion

After years of drought conditions, we were able to observe a year with significant precipitation and discuss preliminary erosion rate trends. Granite trails showed greater overall and annual elevation change. Granite trails also matched the predicted trail classification scheme with red trails having the most and green having the least elevation change. Clay trails show higher variation and require years of high precipitation to observe a possible relationship to the classification system. Based on current observations, clay and granite trails should be managed separately.

6 References

Agisoft. 2014. Agisoft PhotoScan User Manual: Professional Edition, Version 1.1. Agisoft LLC, St Petersburg, Russia. 85pp.

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[HHSVRA] Hollister Hills SVRA Natural Resources Staff. 2012. 2012 Trail Assessment Report, Hollister Hills District. 115pp.

Silveus, J, Teaby A, and Smith D. 2014. Hollister Hills SVRA Trail Erosion Surveys: Spring 2014. The Watershed Institute, California State Monterey Bay, Publication No. WI-2014-09, 20 pp.

Teaby A, Silveus, J, and Smith D. 2013. Hollister Hills SVRA Trail Erosion Surveys: Spring 2013. The Watershed Institute, California State Monterey Bay, Publication No. WI-2013-07, 32 pp.

Weastern Weather Group [Internet]. c 2016. Hollister SVRA Weather Information and Data. cited 2016 June 29. Available from: http://westernwx.com/hollisterhills/.

7 Appendix

The following appendix shows the results of analysis of the surveys with ArcGIS for all 18 sites.

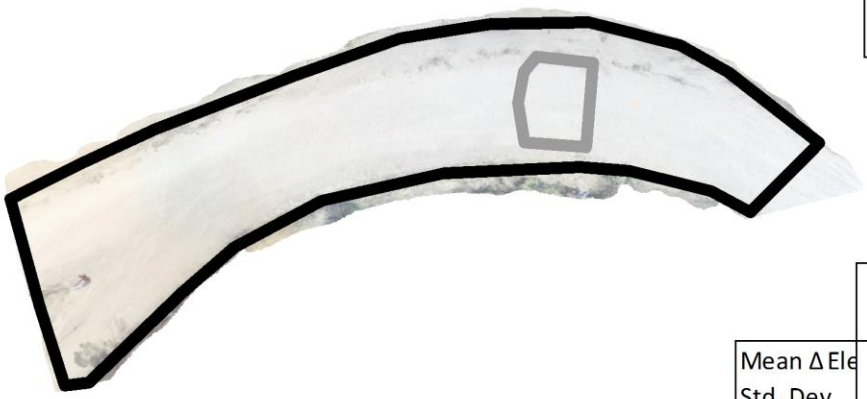
Top half shows 2016 (black polygon) and 2013 (grey polygon) analysis extent overlaid on a photo of the site, a table describing the coverage area for each subsequent survey years, as well as annual (2015 – 2016) and overall (2013 –2016) summary statistics.

In the middle is a "Difference of DEM" (DOD) raster generated by subtracting the altered raster (2016) from the original raster (2013). Positive values indicate sediment deposition and negative values indicate erosion. Total change (2013 –2016) is displayed on the left and annual change (2015 –2016) is displayed on the right.

At the bottom "Cut and Fill" rasters was created with the "Cut and Fill" tool and subtracting the most recent raster (2016) from the original raster (2013), to obtain volumetric data about the change. "Cut" (material removed) is shown in red and "Fill" (material added) is shown in blue.

Backsprings
Clay ATV Red

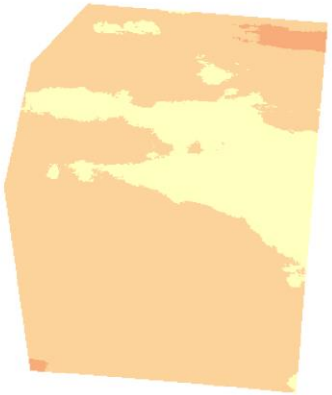
Coverage Area (m^2)	
2013	8.89
2014	8.89
2015	851.28
2016	180.20

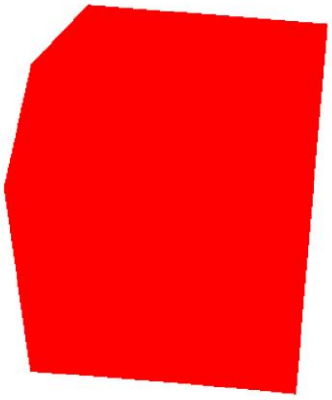


	2013 - 2016 (m)	2015 - 2016 (m)
Mean Δ Ele	-0.12	-0.17
Std. Dev	0.03	0.23
Max Δ Elev	-0.04	0.09
Min Δ Elev	-0.24	-1.32

0 2.5 5 Meters

2013 - 2016





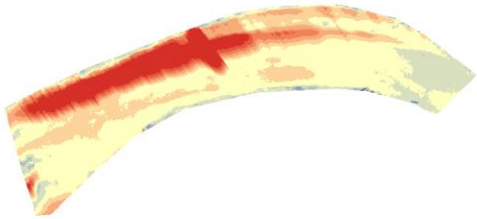
Elevation Change (m)

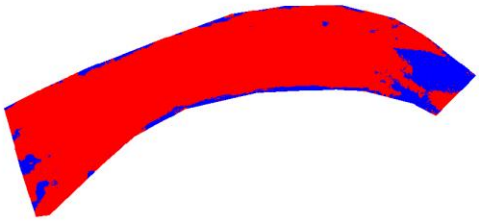
- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

Net Gain/ Loss

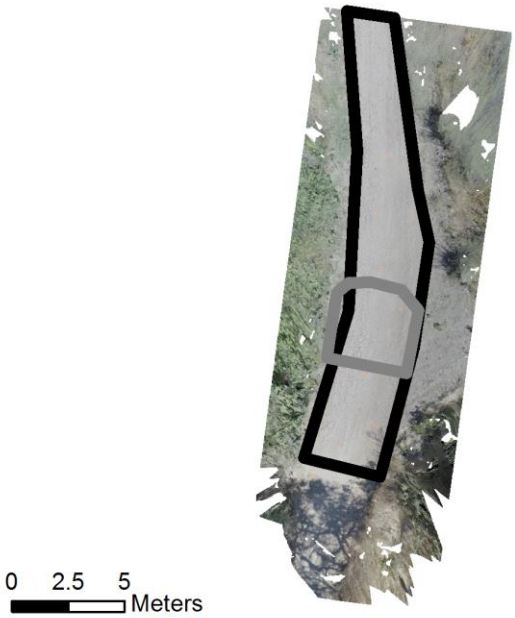
- Net Gain
- Unchanged
- Net Loss

2015 - 2016





Backsprings
Clay ATV Yellow

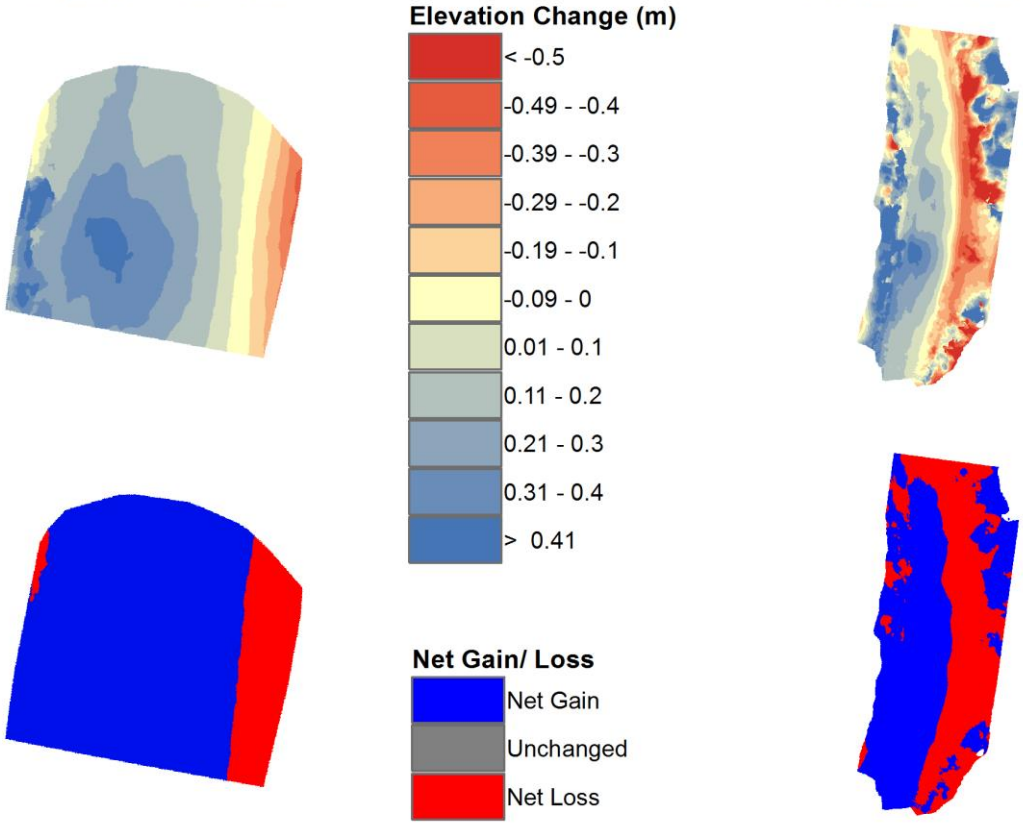


Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	0.16	0.07
Std. Dev	0.18	0.17
Max	0.71	1.05
Min	-0.44	-0.51

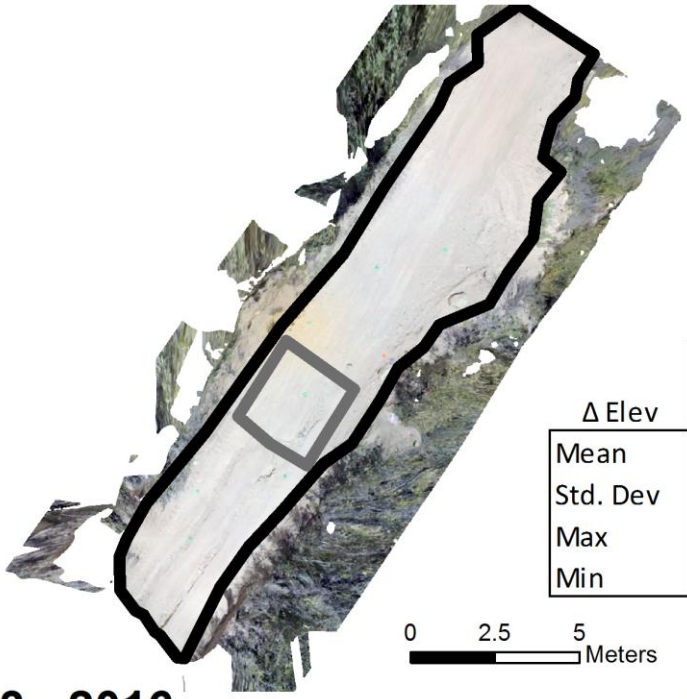
Coverage Area (m^2)	
2013	13.47
2014	23.44
2015	249.98
2016	59.70

2013 - 2016

2015 - 2016



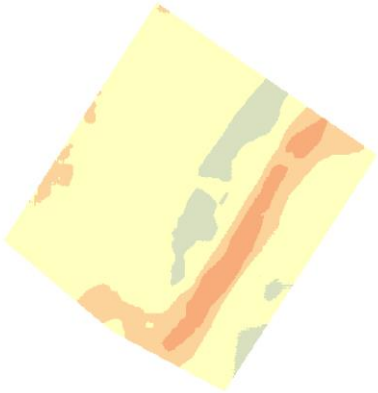
Badger
Granite ATV Red

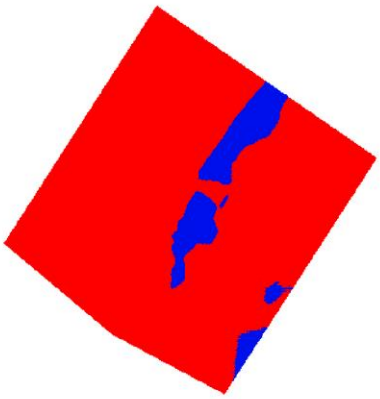


Coverage Area (m^2)	
2013	6.72
2014	6.73
2015	115.77
2016	58.82

Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.07	-0.17
Std. Dev	0.06	0.23
Max	0.09	0.90
Min	-0.25	-1.32

2013 - 2016





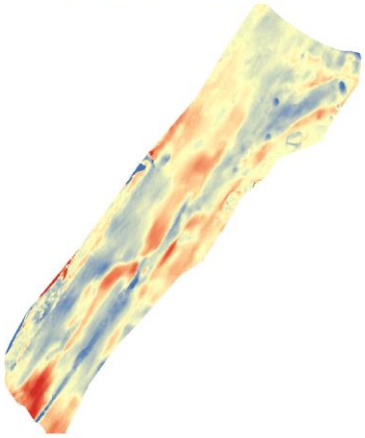
Elevation Change (m)

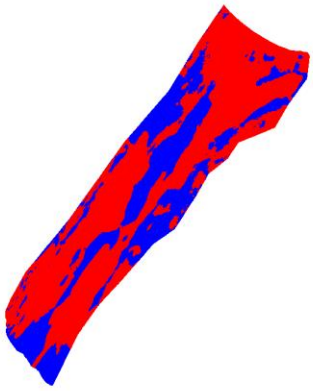
- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

Net Gain/ Loss

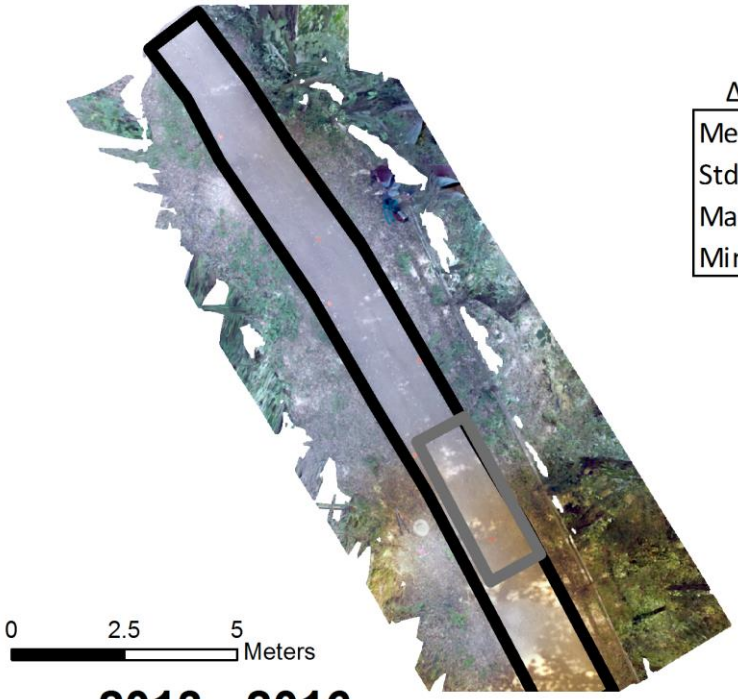
- Net Gain
- Unchanged
- Net Loss

2015 - 2016





Coyote
Granite ATV Green

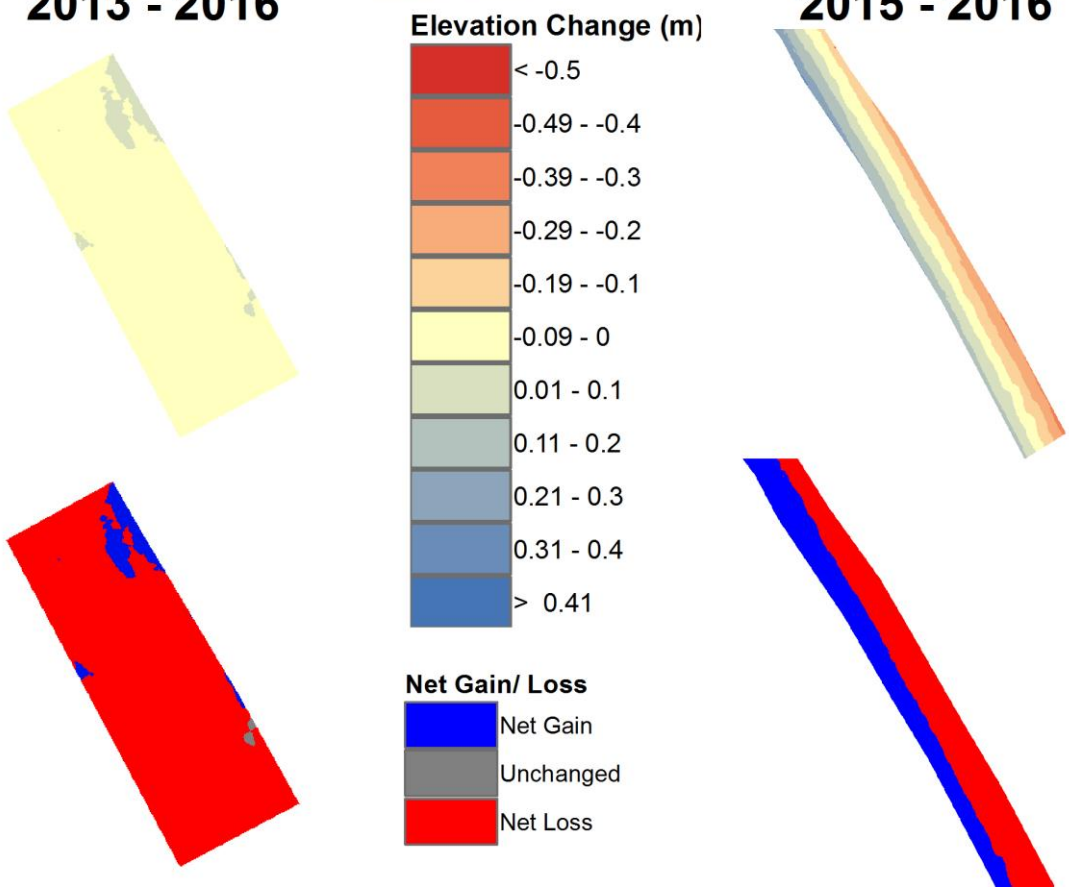


Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.02	-0.03
Std. Dev	0.02	0.14
Max	0.01	0.59
Min	-0.07	-0.54

Coverage Area (m^2)	
2013	4.24
2014	4.26
2015	109.63
2016	26.89

2013 - 2016

2015 - 2016



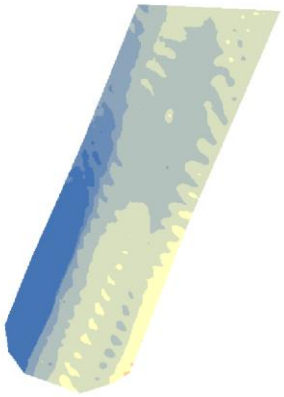
Coyote
Granite ATV Yellow

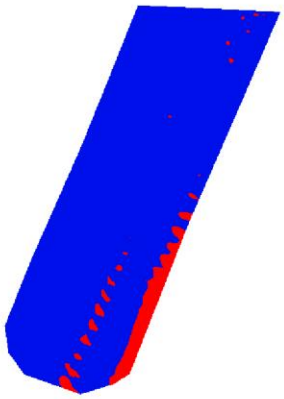
Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	0.17	0.03
Std. Dev	0.18	0.05
Max	1.08	0.47
Min	-0.12	-3.54

Coverage Area (m^2)	
2013	4.16
2014	7.67
2015	144.09
2016	44.16

0 2.5 5 Meters

2013 - 2016





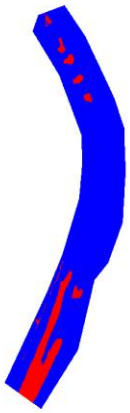
Elevation Change (m)

- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

Net Gain/ Loss

- Net Gain
- Unchanged
- Net Loss

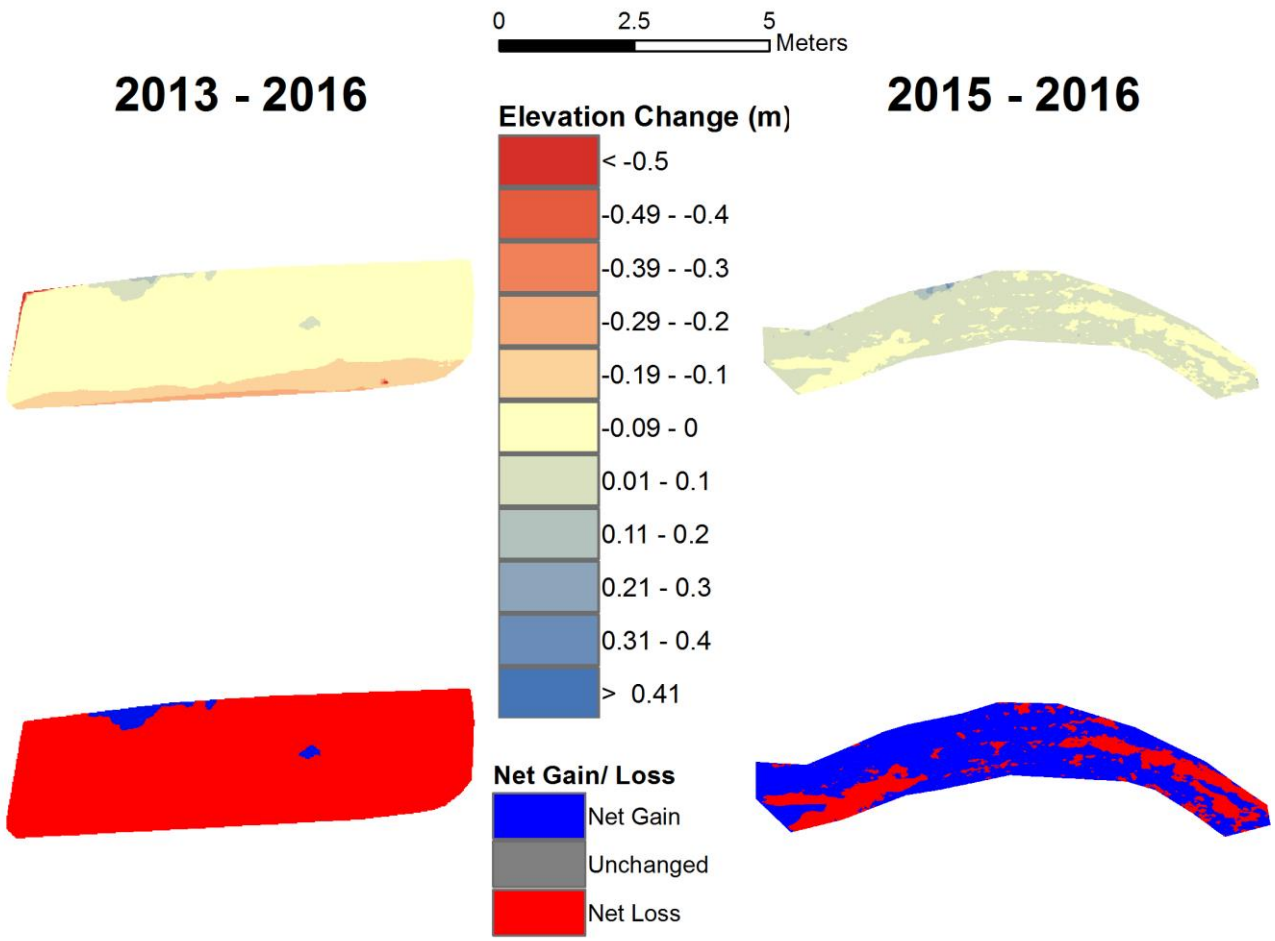
2015 - 2016



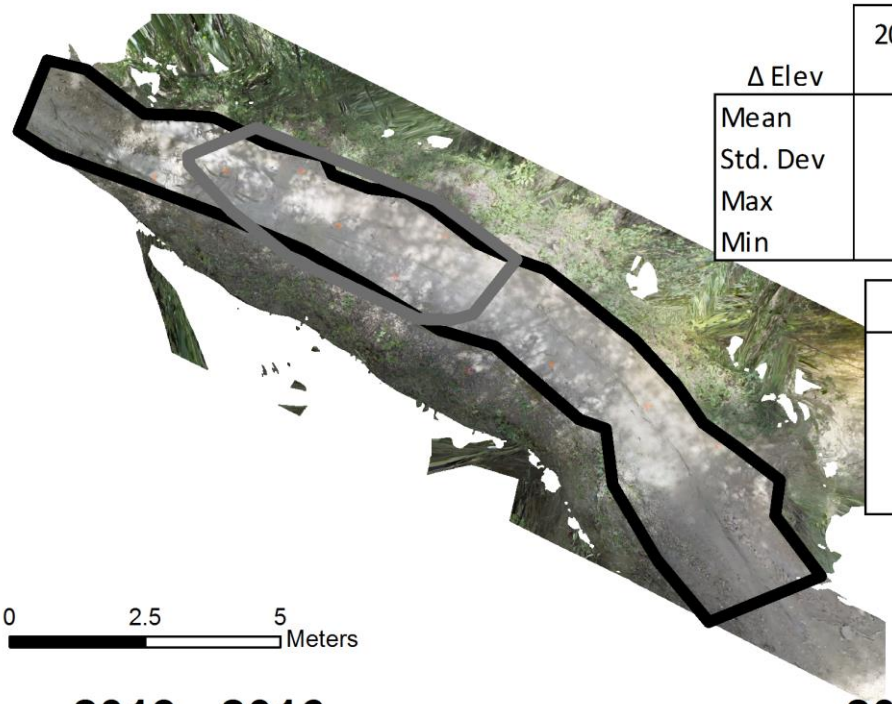
Donnybrook
Granite Single Track Green

Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.07	0.01
Std. Dev	0.06	0.03
Max	0.15	1.32
Min	-1.54	-0.12

Coverage Area (m^2)	
2013	4.40
2014	10.48
2015	99.84
2016	33.58



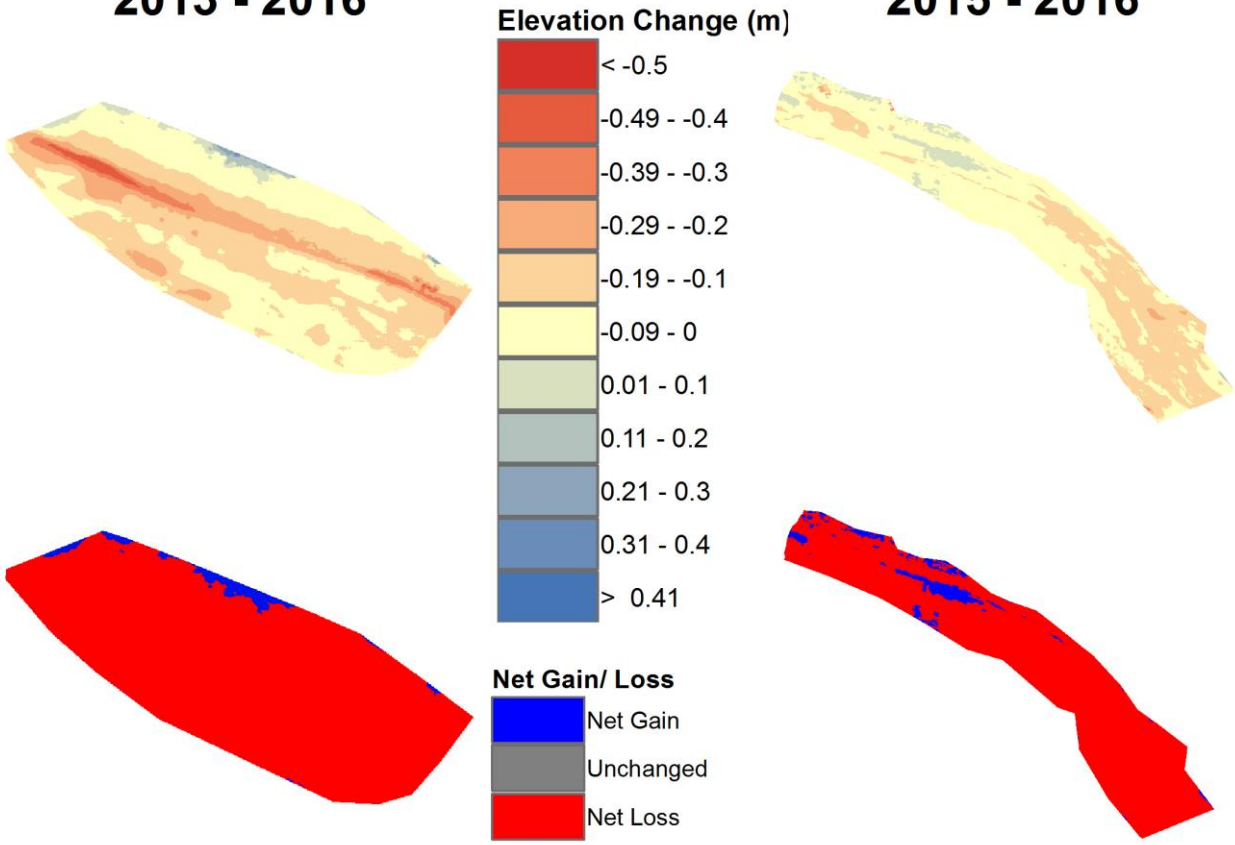
Donnybrook
Granite Single Track Red



Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.12	-0.17
Std. Dev	0.08	0.23
Max	0.34	0.90
Min	-0.48	-1.32

Coverage Area (m^2)	
2013	10.74
2014	6.01
2015	70.82
2016	26.20

2013 - 2016 **2015 - 2016**



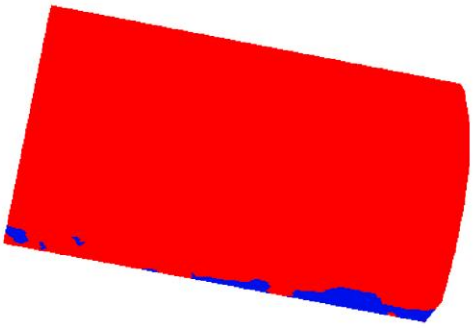
Faultline
Clay Road Green

Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.05	-0.03
Std. Dev	0.02	0.08
Max	0.14	0.26
Min	-0.12	-0.49

Coverage Area (m^2)	
2013	10.44
2014	10.45
2015	170.01
2016	80.85

0 2.5 5 Meters

2013 - 2016



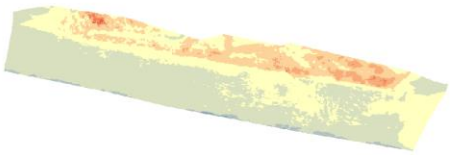
Elevation Change (m)

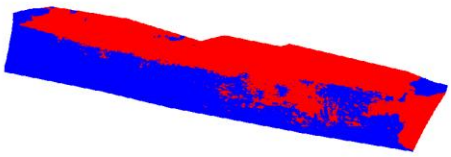
- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

Net Gain/ Loss

- Net Gain
- Unchanged
- Net Loss

2015 - 2016





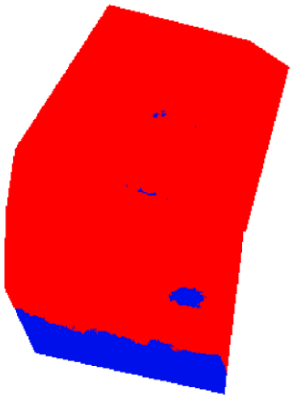
Faultline
Clay Road Yellow

Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.08	-0.03
Std. Dev	0.18	0.06
Max	0.17	0.65
Min	-1.62	-0.23

Coverage Area (m^2)	
2013	5.11
2014	5.10
2015	492.99
2016	97.32

0 2.5 5 Meters

2013 - 2016



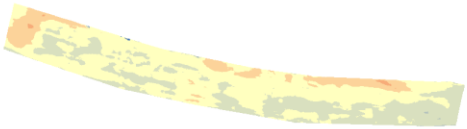
Elevation Change (m)

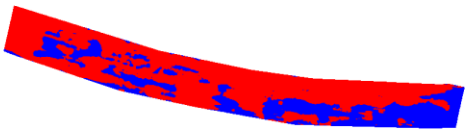
- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

Net Gain/ Loss

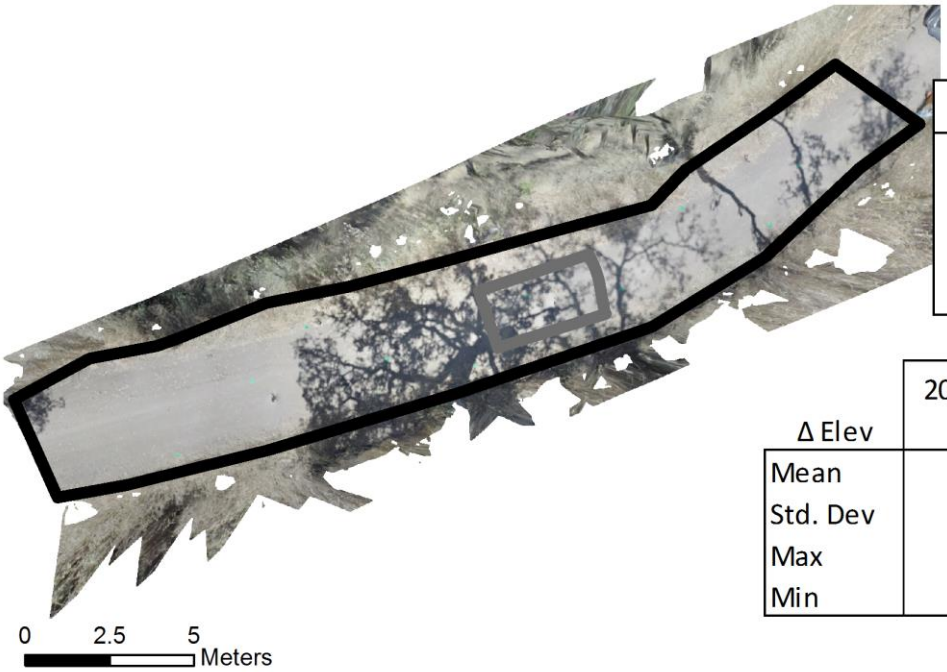
- Net Gain
- Unchanged
- Net Loss

2015 - 2016





4 Corners
Clay ATV Green

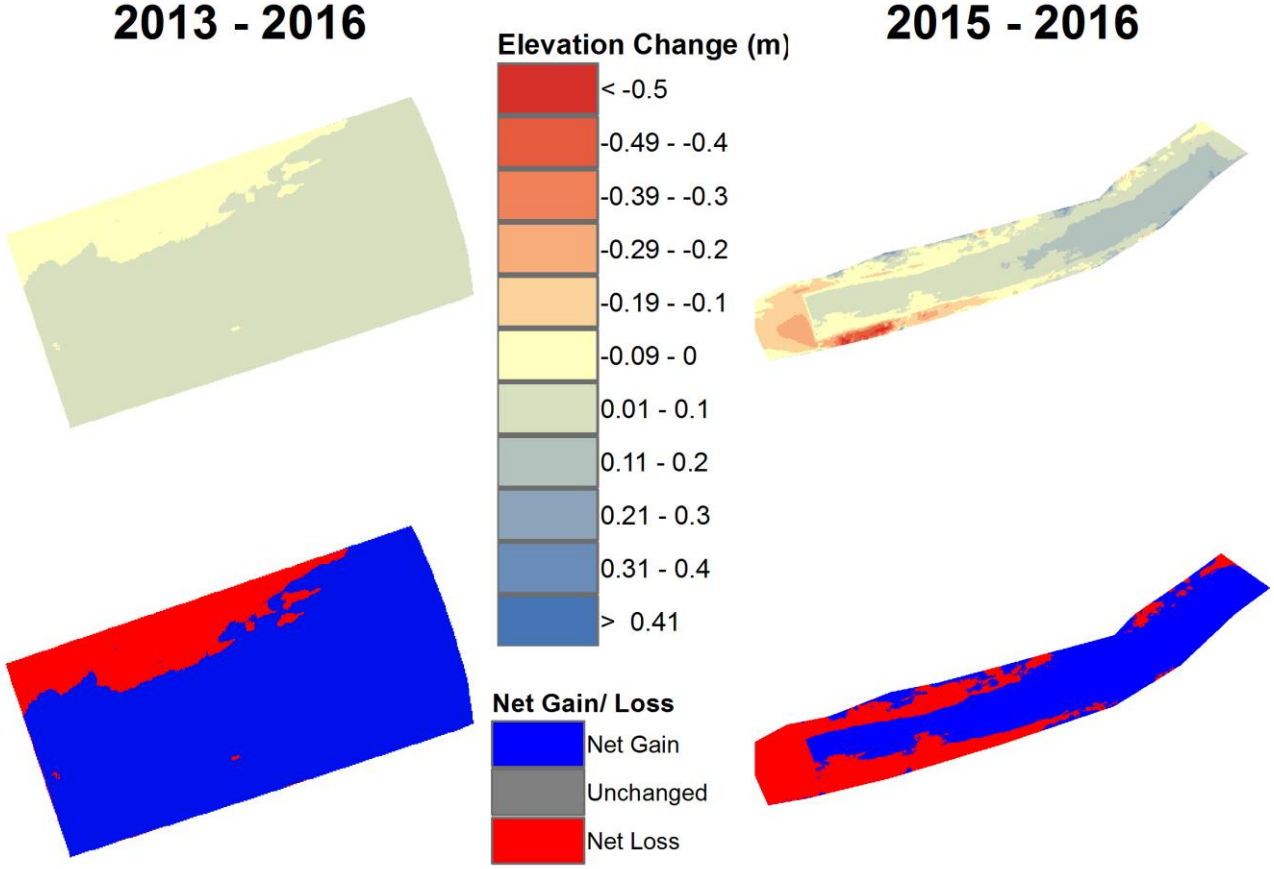


Coverage Area (m^2)	
2013	7.51
2014	6.20
2015	218.10
2016	98.81

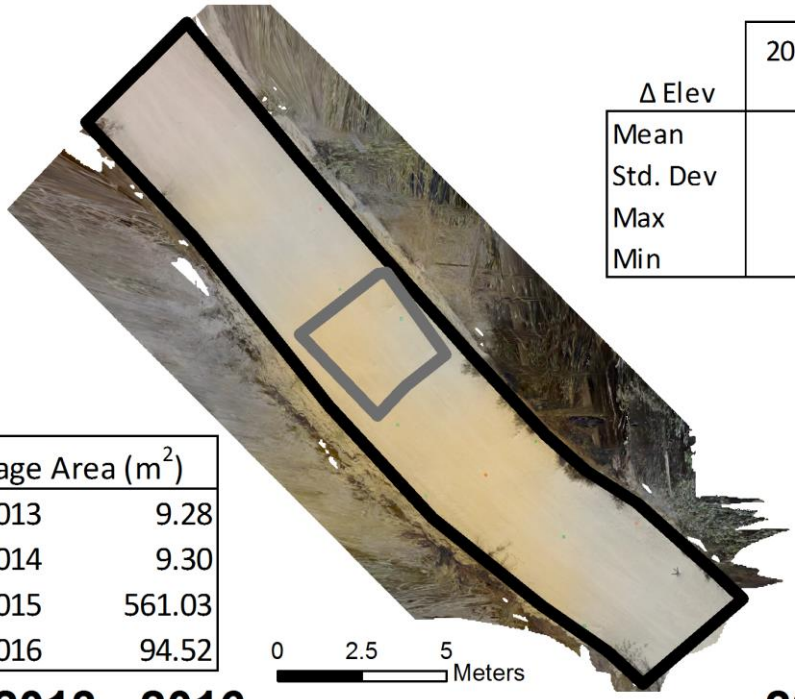
Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	0.01	0.01
Std. Dev	0.01	0.12
Max	0.06	0.46
Min	-0.05	-0.60

2013 - 2016

2015 - 2016



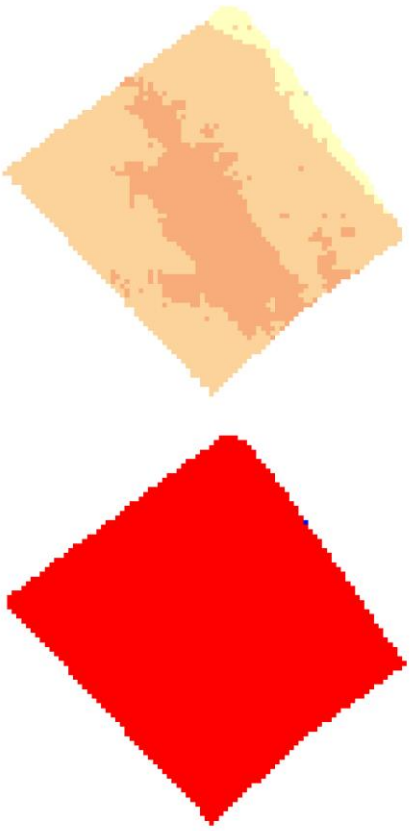
Lake Granite Road Red



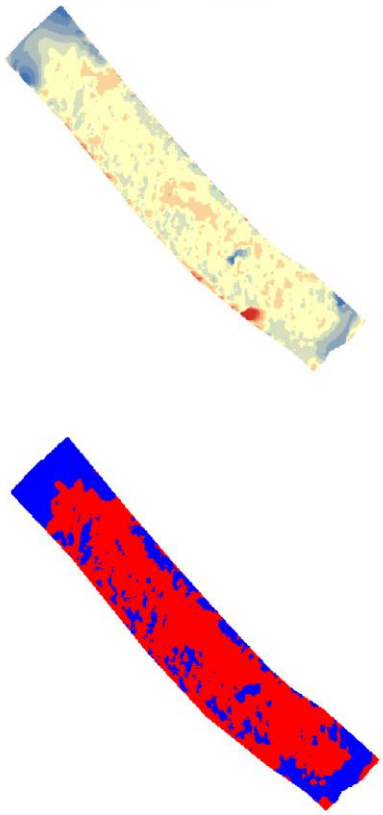
Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.18	0.02
Std. Dev	0.04	0.13
Max	0.00	1.61
Min	-0.26	-1.75

Coverage Area (m^2)	
2013	9.28
2014	9.30
2015	561.03
2016	94.52

2013 - 2016



2015 - 2016



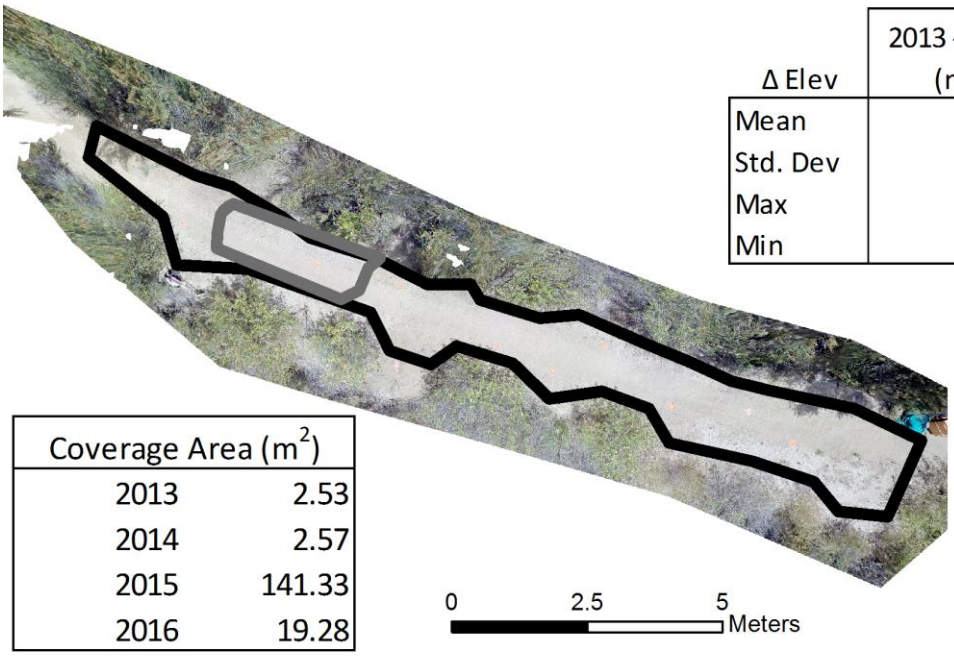
Elevation Change (m)

- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

Net Gain/ Loss

- Net Gain
- Unchanged
- Net Loss

Mystic
Granite Single Track Yellow

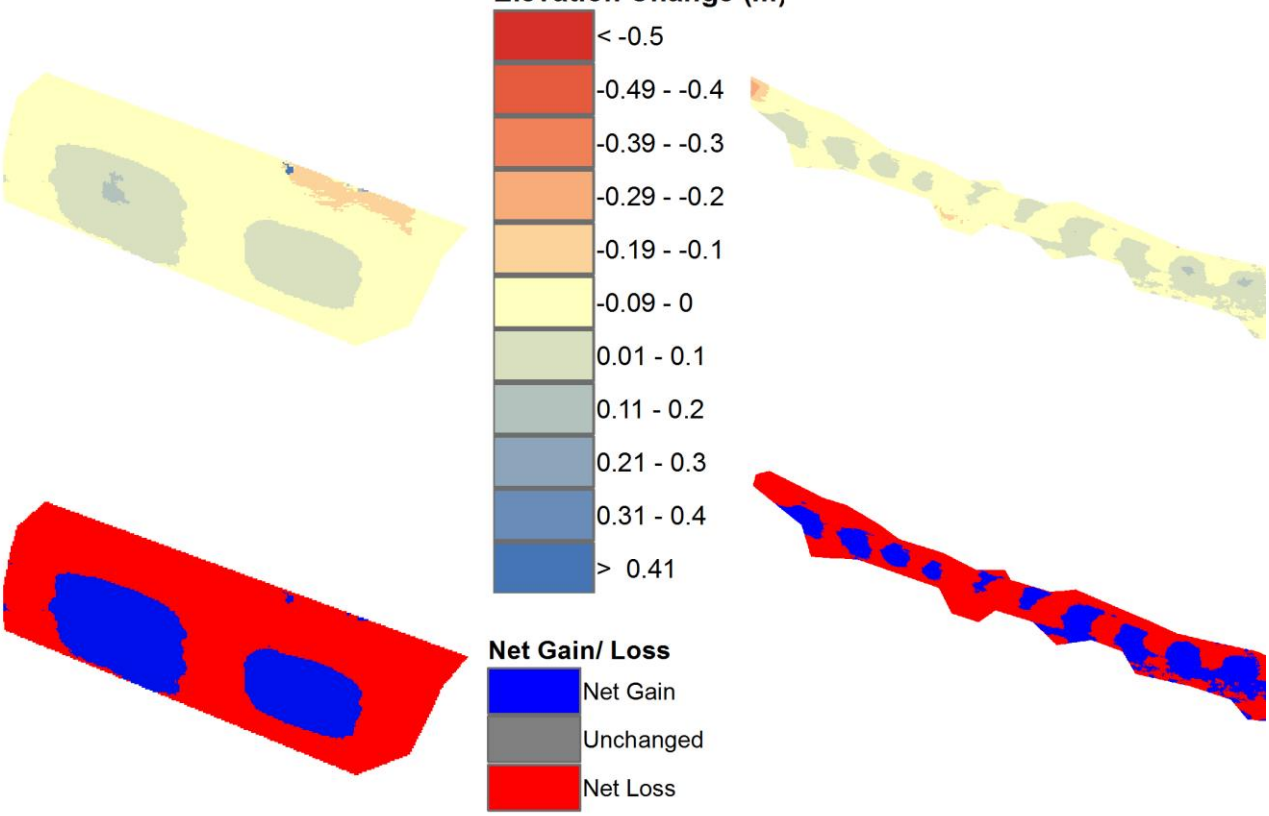


Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.02	-0.02
Std. Dev	0.06	0.05
Max	0.55	0.55
Min	-0.12	-0.42

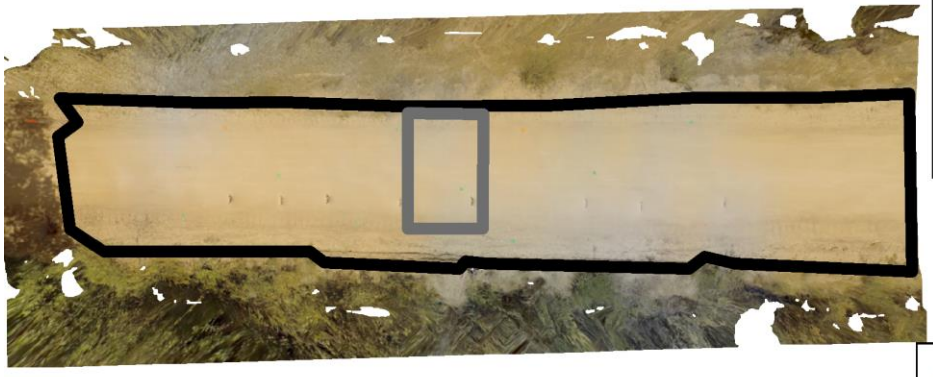
Coverage Area (m^2)	
2013	2.53
2014	2.57
2015	141.33
2016	19.28

2013 - 2016

2015 - 2016



North Canyon
Granite Road Yellow

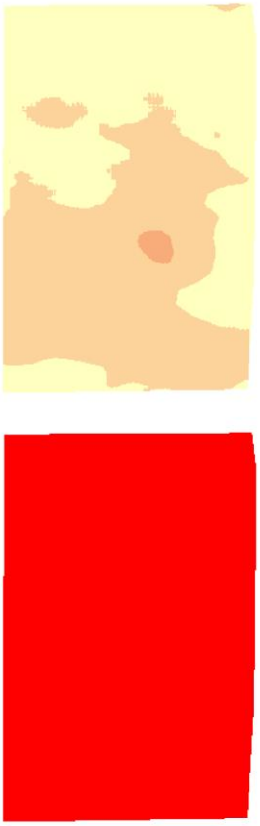


Coverage Area (m^2)	
2013	7.55
2014	7.61
2015	241.45
2016	118.23

Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.10	0.08
Std. Dev	0.03	0.20
Max	-0.03	1.37
Min	-0.21	-0.63

0 2.5 5 Meters

2013 - 2016



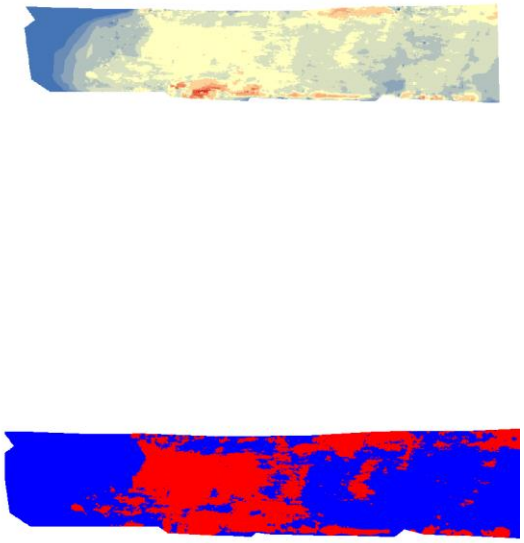
Elevation Change (m)

- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

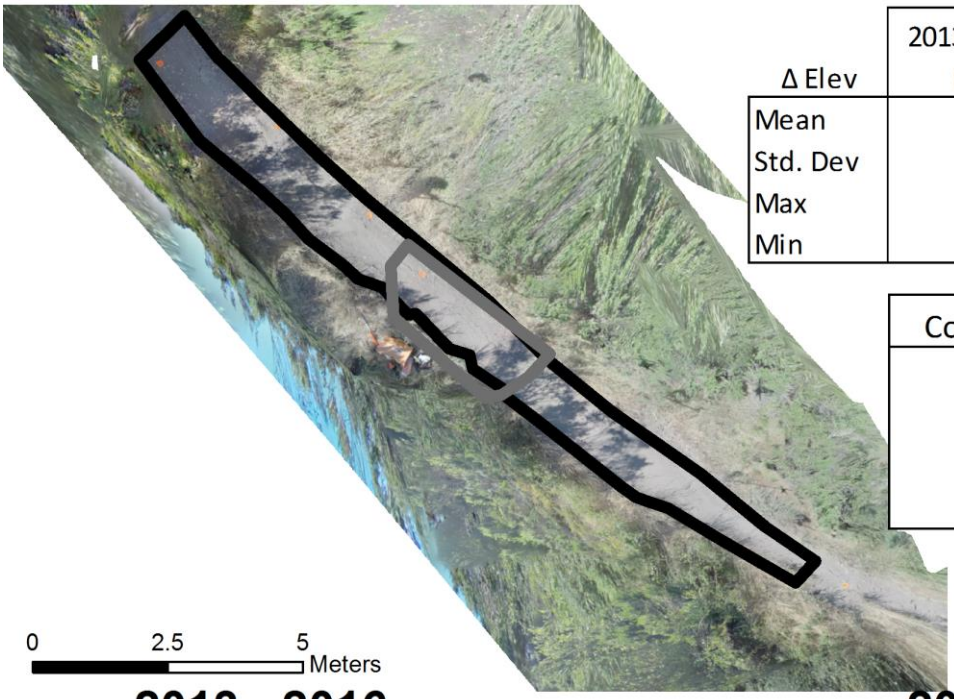
Net Gain/ Loss

- Net Gain
- Unchanged
- Net Loss

2015 - 2016



OK Corral
Clay Single Track Green

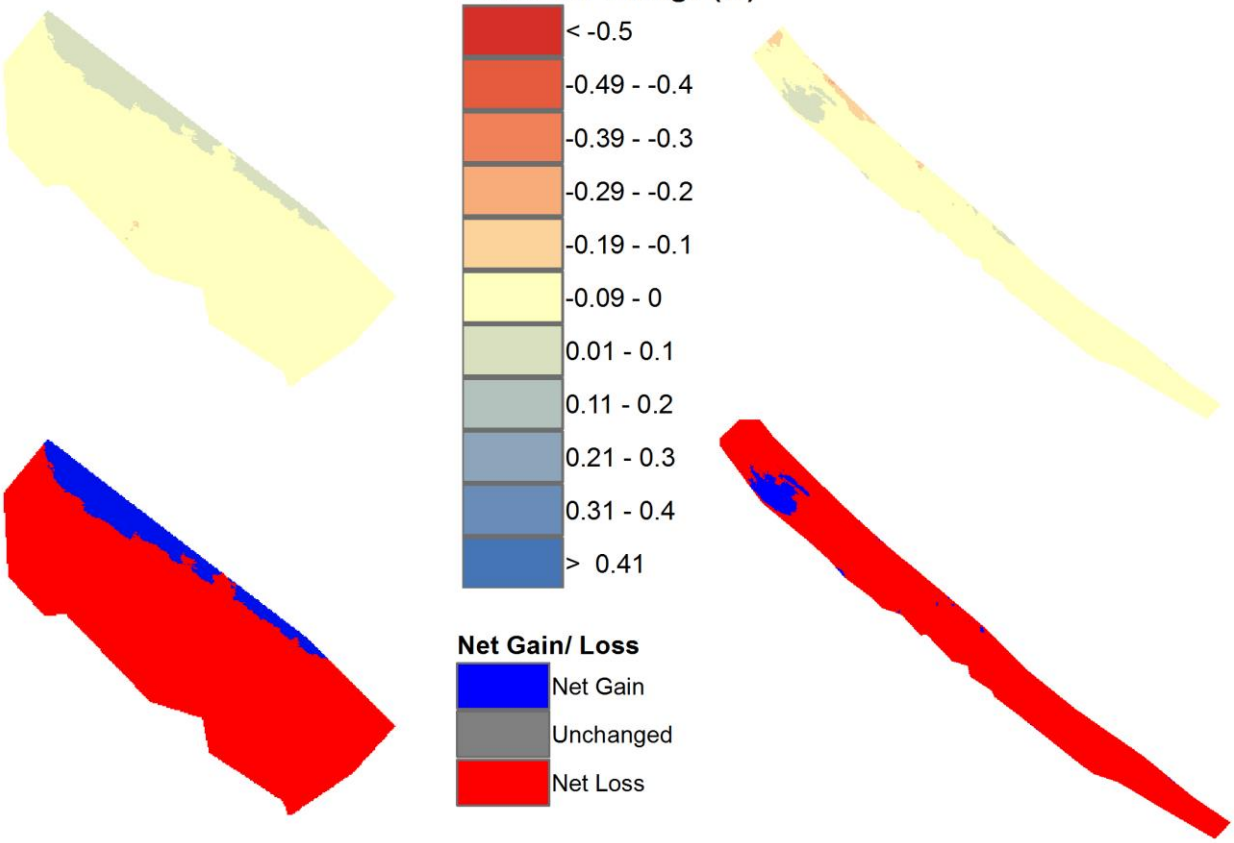


Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.05	-0.04
Std. Dev	0.03	0.03
Max	0.09	0.13
Min	-0.10	-0.27

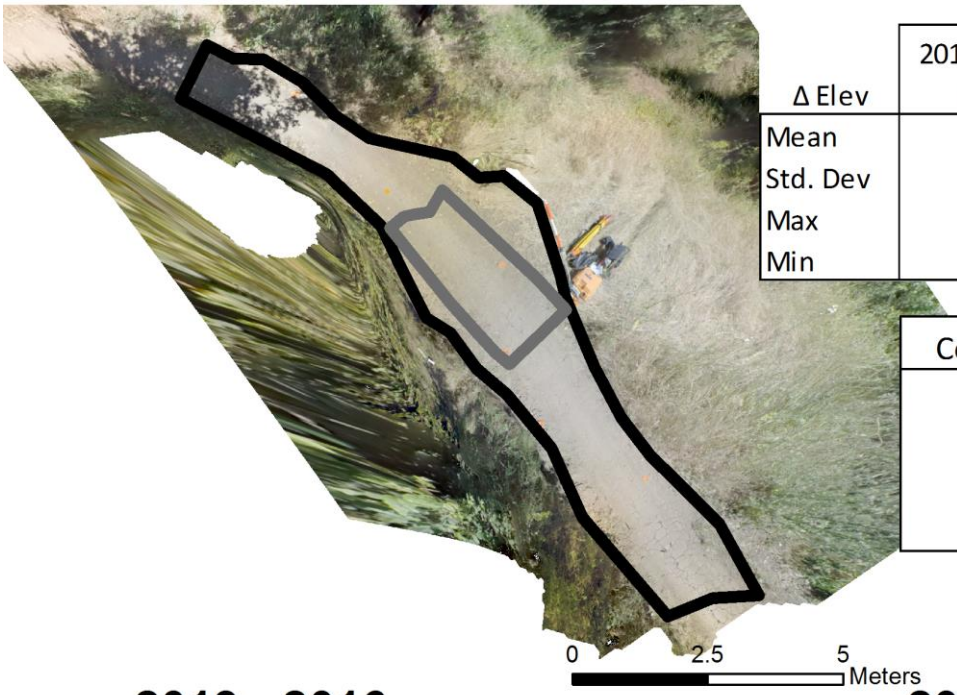
Coverage Area (m^2)	
2013	4.35
2014	2.57
2015	193.12
2016	16.27

2013 - 2016

2015 - 2016

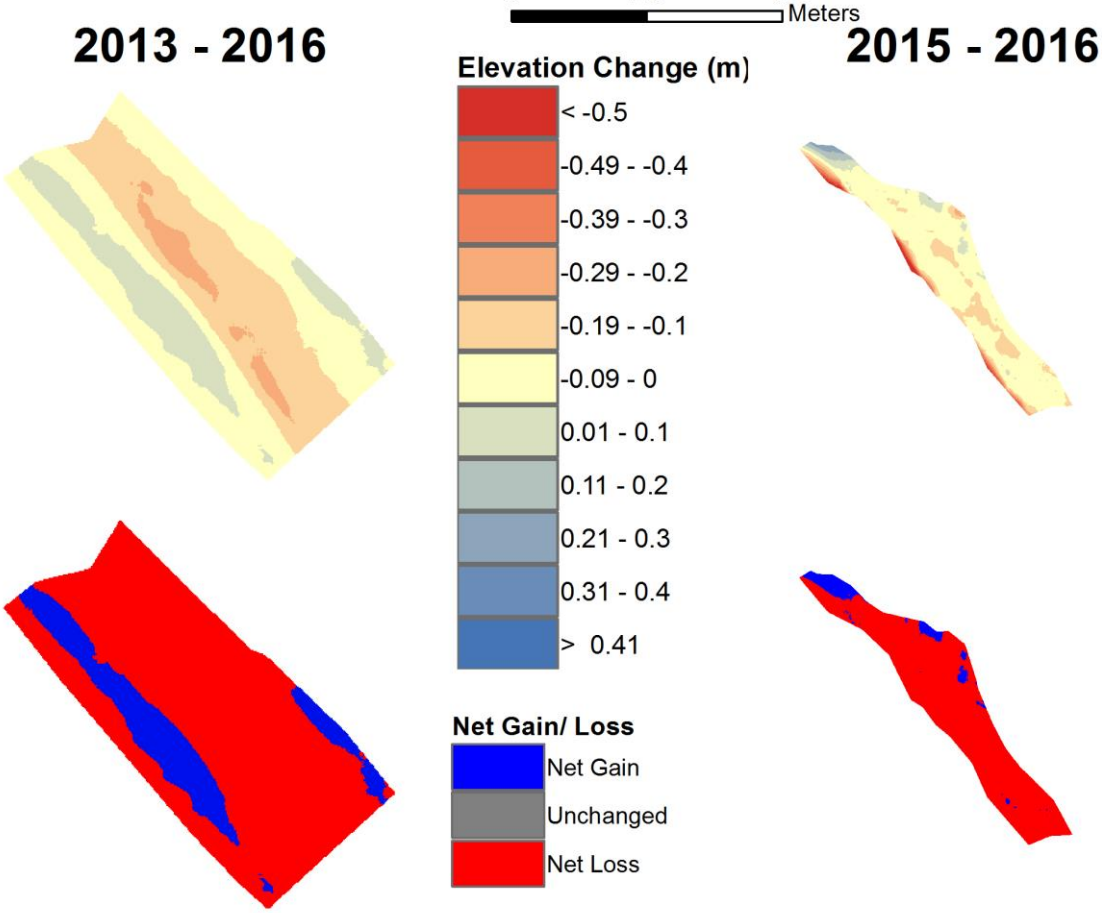


OK Corral
Clay Single Track Yellow



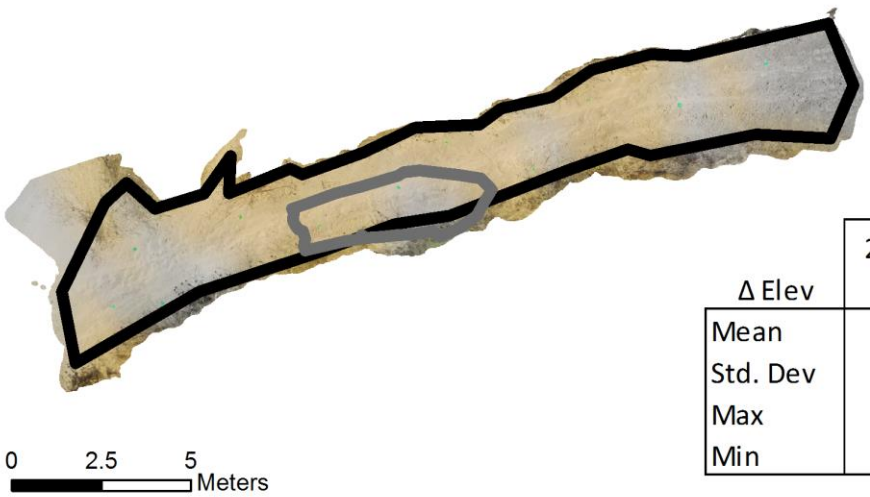
Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.08	-0.08
Std. Dev	0.08	0.10
Max	0.08	0.31
Min	-0.23	-0.75

Coverage Area (m^2)	
2013	4.35
2014	4.37
2015	201.72
2016	23.41



Psych Hill
Clay Single Track Red

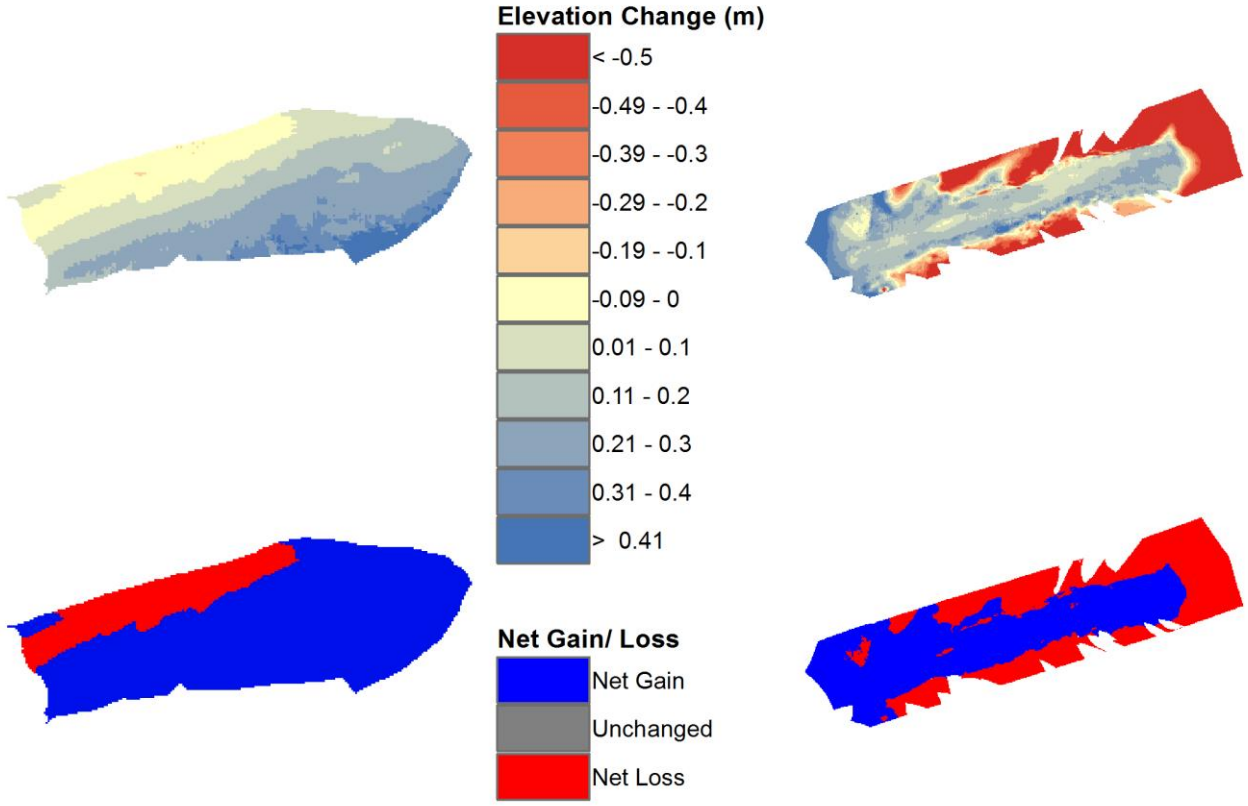
Coverage Area (m^2)	
2013	7.76
2014	N/A
2015	294.62
2016	58.27



Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	0.15	0.12
Std. Dev	0.15	0.13
Max	0.92	0.99
Min	-0.11	-1.10

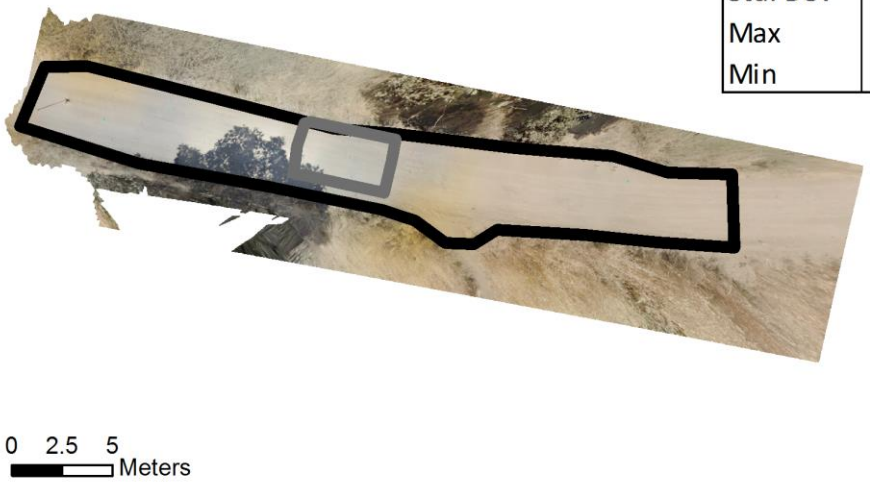
2013 - 2016

2015 - 2016



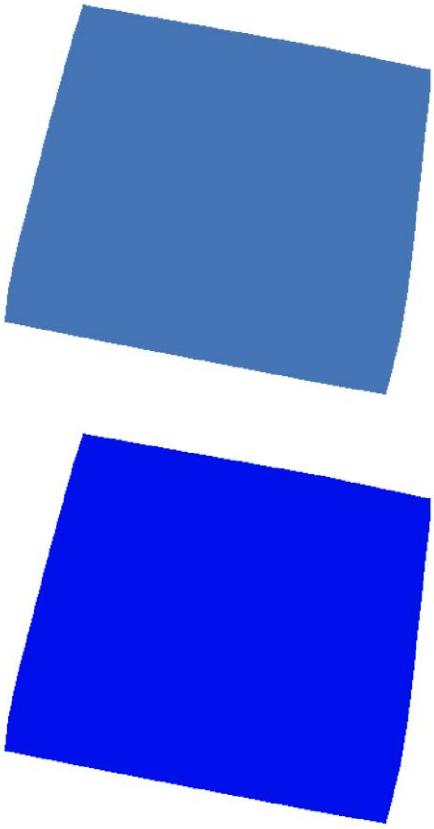
Rancho Clay Road Red

Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	1.38	1.29
Std. Dev	0.05	0.37
Max	1.50	2.33
Min	1.26	-0.19



Coverage Area (m^2)	
2013	9.10
2014	12.37
2015	633.47
2016	137.89

2013 - 2016



Elevation Change (m)

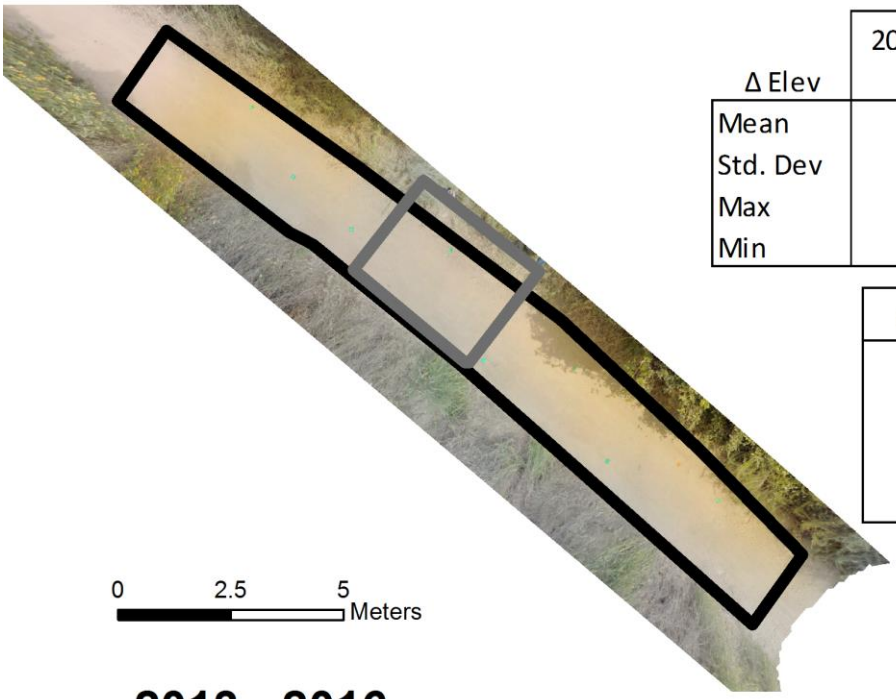
- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

Net Gain/ Loss

- Net Gain
- Unchanged
- Net Loss

2015 - 2016

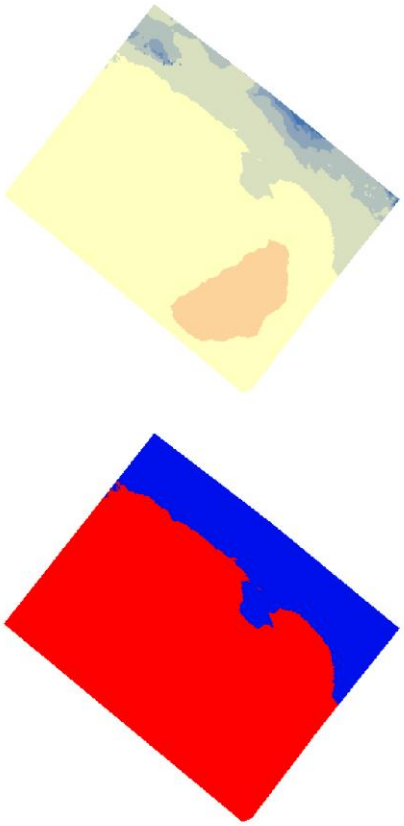
Sage Granite Road Green



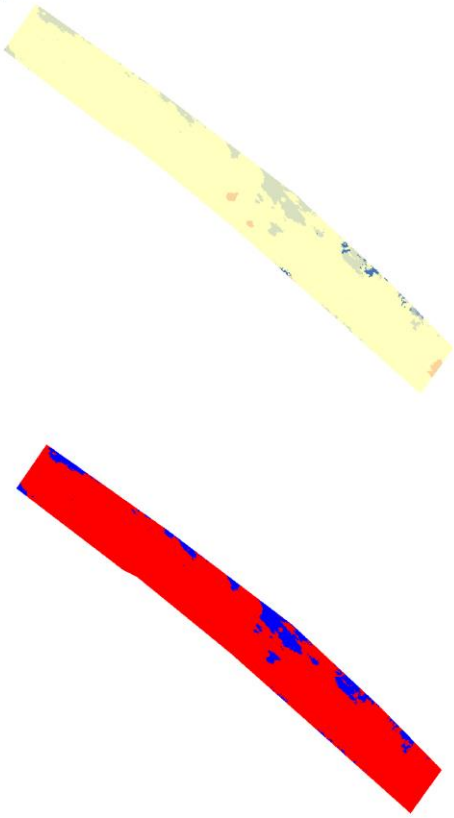
Δ Elev	2013 - 2016 (m)	2015 - 2016 (m)
Mean	-0.02	-0.03
Std. Dev	0.08	0.06
Max	0.60	1.80
Min	-0.16	-0.26

Coverage Area (m^2)	
2013	8.39
2014	8.40
2015	197.12
2016	37.84

2013 - 2016



2015 - 2016



Elevation Change (m)

- < -0.5
- -0.49 - -0.4
- -0.39 - -0.3
- -0.29 - -0.2
- -0.19 - -0.1
- -0.09 - 0
- 0.01 - 0.1
- 0.11 - 0.2
- 0.21 - 0.3
- 0.31 - 0.4
- > 0.41

Net Gain/ Loss

- Net Gain
- Unchanged
- Net Loss