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Hollister Hills SVRA

Trail Erosion Surveys

Summer 2018

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Executive Summary

In 2012 environmental scientists at Hollister Hills State Recreational Vehicle Area (SVRA) issued a report prioritizing 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 annual topographic surveys. The sample sites were selected to include variability in trail type: road, all-terrain vehicle (ATV), and single-track; soil type: clay and granitic; and trail sustainability: green, yellow, and red. In 2013 a baseline digital elevation model was created for each site using a programmable total station. Each site has been annually resurveyed since that time. The current report presents and analyzes data from June 2018. Changes in the elevation of sites were computed by raster subtraction in ArcGIS. Plots and statistical analyses were done using R software.

Annual trail erosion in 2018 was driven by annual rainfall of 10.75 inches. Ten of the 18 sites were mechanically-, or hand-graded in 2018. One site (Psych Hill) was not analyzed. The overall average topographic change for the entire study area was 0.03 m of erosion. Green, Yellow and Red sites respectively showed 0.03 m, 0.01 m and 0.05 m of erosion. On average, clay soil sites lost 0.06 m, while granitic soil sites did not change. Sites with Roads, ATV, and Single-track use respectively lost 0.01 m, 0.05 m, and 0.01 m of soil. Average erosion of unmanaged sites was 0.06 m of erosion while managed sites lost no soil on average.

Five years of data are summarized and plotted to indicate that:

- red trails erode significantly more than yellow or green trails when five year cumulative change is computed,
- rainfall does not correlate with erosion rates,
- trail type and soil type do not greatly influence erosion rates,
- management activities reduce annual erosion rates to near 0 m/yr.

Contents

1 Introduction

1.1 Overview

In 2012 Hollister Hills State Recreational Vehicle Area (SVRA) (Fig. 1) environmental scientists created an index to rate the sustainability of the trails in the park: green (acceptable), yellow (marginal), and red (action needed). The rating index was based on a visual assessment of the trail physical context and condition (HHSVRA 2012), as outlined in California Department of Parks and Recreation Soil Conservation Guidelines/Standards for Off-Highway Vehicle Recreation Management (CDPR 2008). This effort was undertaken to inform best management practices that would optimize soil conservation in the park. While the rating system was based upon observations of parameters that are commonly understood to foster or retard erosion, the park staff recognized the need to quantitatively validate and calibrate the system.

In 2013, park staff collaborated with Cal State Monterey Bay to study the annual erosion of a subset of trails that had been visually indexed. The study included 18 sites across the SVRA to account for factors that might control erosion rates: geologic substrate (Granitic and Clay), vehicle use types (Single Track, ATV, and Road), and trail erodibility index (Green, Yellow and Red; Fig. 2). The sites were selected to have redundancy in each variable to facilitate statistical analysis of the factors that influence trail erosion.

Trail erosion was also analyzed based upon whether or not they were actively “managed” in a given year. Trail management, whether done by hand-tool or mechanical means, is generally restricted to replacing the side-cast erosion berm back into the tread of the trail. For our study, a trail is considered “managed” if the activity occurred at any time between two consecutive surveys. Surveys were typically conducted weeks to months following management action. The Rancho assessment site (Fig. 2) is the only site to have been regraded with imported material during the study period. In 2015, before the 2016 surveys, the Rancho site was raised approximately 1 m by the addition of material imported from the cleanout of Lodge Lake retention basin. The 2016 survey from that site has been excluded from further analysis.

1.2 Trail Management

Trail maintenance is performed to reduce soil erosion, and includes a well-established annual workflow. During the summer months, annual trail assessments are performed to establish maintenance priorities, future restoration projects, trail rehabilitation projects, and trail reroutes. Trail maintenance typically coincides with the fall and winter months, but varies across the park unit depending on soil type.

Trail maintenance activities are scheduled during the year based upon soil type (granitic and clay-rich) and rainfall patterns. Timing is essential and relies upon adequate soil moisture to achieve the desired level of compaction. For example, granitic sections of the park are maintained one to two days following a rain event whereas clay-based trails are maintained prior to rain events and before they are completely saturated. Granitic soils in the park drain rapidly, thus providing a short window to work the tread surface following a rain event. Alternatively, clay-based trails, when fully saturated, are nearly impassable to vehicular traffic and are difficult to work with a piece of heavy equipment because the material tends to clump together and stick to the equipment's blade. Therefore, maintenance activities on clay-based trails are performed during the fall before large-scale rain events and in the late spring as the soil begin to dry.

Trail drainage is of the highest priority for management of the trail system. Early in the season, and typically after the first few rains, an equipment operator will use a bulldozer in a limited area (spot maintenance) to maintain drainage features such as water bars, rolling dips and inside drains. Following large-scale rain events, and particularly in the granitic trails, the operator uses a road grader to pull in material displaced to the outsides of the trail from OHV use, and use that material to fill low spots, smooth breaking-bumps, fill ruts on the tread surface, and to reestablish the outslope. The majority of trails in the park are outsloped to promote sheet flow drainage across the trail. Wet weather and muddy condition closures are also enforced at the park to prevent soil loss and trail damage. The clay-based trails in the park are closed to OHV use during wet weather, and are not reopened until the tread surface has had time to drain and dry.

The width of a particular trail will dictate the most efficient tools for trail maintenance. A medium sized bulldozer and a road grader are typically used to maintain roads; ATV trails are maintained with a smaller dozer (approximately eight foot wide blade); single track trails are maintained by hand crew or with a trail dozer (four foot wide blade).

1.3 Study Approach

The first trail surveys set the baseline topography in 2013 (Teaby et al. 2013). In each year thereafter, repeat surveys have estimated the annual and cumulative vertical erosion in each study site (Silveus et al. 2014; Chow et al. 2015, 2016; Smith et al. 2016; Morris et al. 2018).

The survey methods used in the study have evolved through time, but local elevation changes have been consistently linked to 3D benchmarks established at each site in 2013. A programmable total station was used in the 2013 and 2014 surveys. Thereafter, very low altitude (~3 m) photogrammetry has been achieved by attaching a gimbaled Go-Pro camera to a long pole. The switch to photogrammetric techniques produced much denser topographic data sets, and fostered a gradual increase in assessment area of each site. Agisoft PhotoScan software was used to create orthomosaic images and digital elevation models from 2015 to 2017. In 2018 we transitioned to Pix4D software for data processing. This report documents the topographic changes between May 2017 and May 2018—a time span that includes all of the significant precipitation events of the 2018 water year.

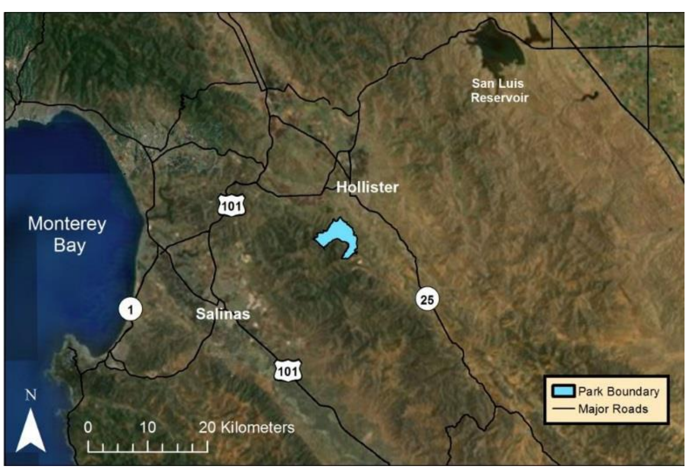

Figure 1. Hollister Hills State Vehicular Recreation Area is found northeast of Salinas.

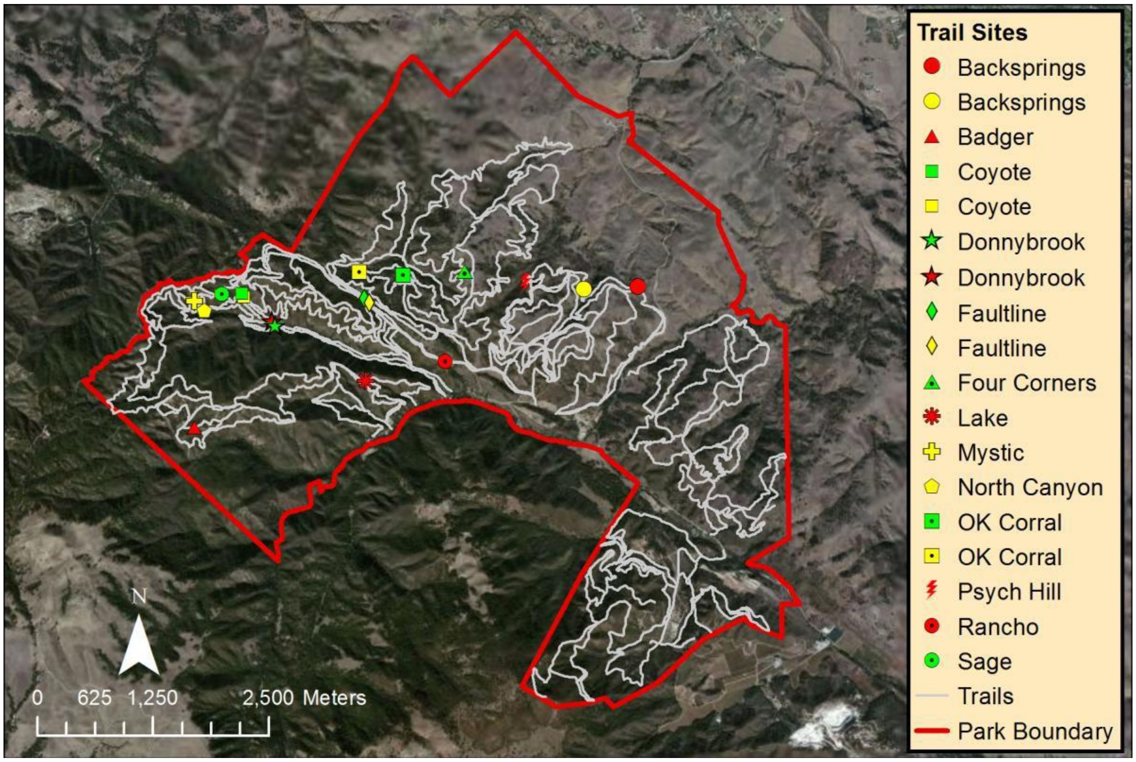

Figure 2. Trail site locations within Hollister Hills State Vehicular Recreation Area, Hollister, CA. Colors correspond to visual rating index.

Approximately 10.75 inches of rain fell between the 2017 and 2018 trail surveys. That value represents the median of the 8 years of record, and is drier than the average of 14.11 inches (Table 1; Fig. 3).

Table 1: Hollister Hills SVRA precipitation data obtained from Western Weather Group (2018).

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	**Total**
2011	0.89	2.29	4.15	1.81	4.07	4.57	0.20	1.11	0.37	0.00	0.00	0.00	**19.46**
2012	0.83	1.96	0.11	2.28	0.62	2.62	2.18	0.03	0.06	0.03	0.00	0.00	**10.72**
2013	0.27	2.54	4.35	0.98	0.75	0.60	0.21	0.00	0.00	0.00	0.00	0.08	**9.78**
2014	0.11	0.28	0.34	0.20	2.72	1.56	0.76	0.00	0.00	0.00	0.00	0.08	**6.05**
2015	1.05	0.51	5.23	0.00	1.26	0.17	1.14	1.24	0.00	0.02	0.06	0.08	**10.76**
2016	0.18	3.42	2.97	5.67	0.88	5.23	0.87	0.08	0.00	0.00	0.00	0.00	**19.30**
2017	2.76	1.53	2.20	9.70	6.27	1.91	1.55	0.06	0.06	0.00	0.00	0.05	**26.09**
2018	0.23	1.43	0.29	2.48	0.27	4.62	1.43	0.00	0.00	0.00	0.00	0.00	**10.75**
Monthly Average	**0.79**	**1.75**	**2.46**	**2.89**	**2.11**	**2.66**	**1.04**	**0.32**	**0.06**	**0.01**	**0.01**	**0.04**	

Annual Average **14.11**

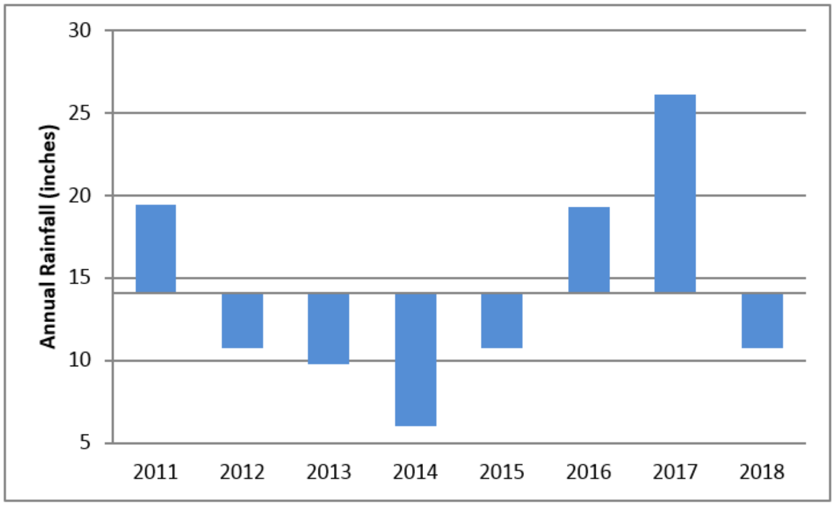

Figure 3. Annual precipitation at Hollister Hills SVRA. Values shown with respect to the mean value of 14.11 inches.

2 Methods

2.1 Field Survey

Seventeen of the original 18 sites surveyed in 2017 were revisited in 2018 and surveyed using the same local benchmarks (BM) for horizontal and vertical referencing. At each site, one BM with known 3D position was occupied with a 3" Nikon total station. A backshot to a second BM establish the horizontal control.

Within the survey footprint of the 2017 survey, 10 cm x 10 cm, plastic square ground control points (GCPs) were placed in a zigzag pattern throughout the trail and temporarily nailed in place with a spike. The local 3D coordinate of each GCP was found using the total station. Surveys were closed with errors typically under 0.01 m in each dimension.

Low altitude 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. The photos for each site were processed using Pix4D (https://www.pix4d.com/). In previous years Agisoft Photoscan was used (https://www.agisoft.com/). Both software packages were used on one site to assess product compatibility. The elevation differences were inconsequential, so we are confident in assessing geomorphic change with either software package.

2.2 Surface Modeling

For each site, we selected photos that contained multiple GCPs, and had a clear view of the trail from different locations with minimal vegetation interference. We uploaded the best subset of photos into Pix4D Software and exported a digital surface model (DSM) and orthophoto for each site.

Table 2 summarizes the site parameters and root mean square error (RMSE) on GCP location. Horizontal ground resolution was a few mm/pixel, and the vertical RMSE of GCPs was typically a few mm (Table 2).

Table 2: Table showing the locations, site condition, usage, soil type, 2018 analysis area and input parameters (number of photos, number of GCPs), as well as resulting GCP 3D and vertical (Z) root mean square error (RMSE) and ground resolution for each site's DEM.

Trail Location	Condition	Usage	Soil Type	Area (m^2)	Photos #	GCPs #	3D RMSE (m)	Z RMSE (m)	Resolution (mm/pix)
OK Corral_1	**Green**	Single Track	Clay	10	138	10	0.008	0.016	5
Donnybrook_2	**Green**	Single Track	Granite	10	86	6	0.002	0.002	6
4 Corners	**Green**	ATV	Clay	82	123	10	0.135	0.085	6
Coyote_1	**Green**	ATV	Granite	39	144	7	0.003	0.002	3
Faultline_2	**Green**	Road	Clay	47	199	11	0.015	0.017	4
Sage	**Green**	Road	Granite	38	102	6	0.003	0.003	4
OK Corral_2	**Yellow**	Single Track	Clay	5	62	7	0.005	0.007	3
Mystic	**Yellow**	Single Track	Granite	15	156	6	0.009	0.004	5
Backsprings_2	**Yellow**	ATV	Clay	52	155	13	0.006	0.007	3
Coyote_2	**Yellow**	ATV	Granite	53	137	10	0.006	0.009	3
Faultline_1	**Yellow**	Road	Clay	21	152	10	0.004	0.004	3
North Canyon	**Yellow**	Road	Granite	134	199	9	0.004	0.003	4
Psych Hill	**Red**	Single Track	Clay			not surveyed in 2018			
Donnybrook_1	**Red**	Single Track	Granite	16	120	8	0.006	0.003	3
Backsprings_1	**Red**	ATV	Clay	112	129	11	0.007	0.009	4
Badger	**Red**	ATV	Granite	60	126	6	0.007	0.008	4
Rancho	**Red**	Road	Clay	89	137	11	0.009	0.01	7
Lake	**Red**	Road	Granite	93	94	7	0.006	0.009	3

2.3 Analysis

ArcMap (v. 10.6) was used to create a difference of DSMs (DODs) for every site by using Raster Calculator to subtract the 2017 DSM from the 2018 DSM. A mask was created for each raster to restrict the DOD analysis to the trail tread and to avoid overhanging vegetation. The area and average vertical change of each site were extracted from ArcMap. The 2018 elevations, areas, and volumes obtained from this process were compared with those of 2017, 2016, 2015, 2014, and 2013 values to quantify both annual and total change. R Software was used to analyze and generate graphs of the data using the "ggplot2" package (R Core Team 2013). Precipitation data were obtained from the Hollister Hills Weather Monitoring Station within the park boundary (Western Weather Group 2017).

Sites were analyzed to assess the reliability of the sustainability index to predict relative erosion rates. Sites were then grouped to assess the relative importance of soil type, trail type, maintenance and annual precipitation on soil erosion rate. Lastly, the study was summarized by cumulative change over the five years of observation.

3 Results

3.1 Annual Erosion and Annual Averages

Table 3 provides the spatially-averaged annual elevation changes measured at each site, parsed by soil type, trail type, classification, and whether or not the site was managed. The erosion history of each site is located in Appendix A. The annual averages for each of the 5 years shows that minor net erosion occurred in each year, except for 2017 when the average response was trail deposition (Table 4; Fig. 4).

Table 3: Annual elevation change at each site. Site condition is from HHSVRA (2012). Positive numbers indicate deposition and negative numbers indicate erosion. Grey indicates sites that were managed before the annual survey. Blue value is site with imported material—excluded from analysis.

				Δ Elev (m)				
Trail Location	Condition	Trail Type	Soil Type	17-18	16-17	15-16	14-15	13-14
OK Corral_1	**Green**	Single Track	Clay	-0.031	0.037	-0.039	0.000	-0.007
*Donnybrook_2	**Green**	Single Track	Granite	0.022	-0.016	0.007	-0.036	-0.045
*4 Corners	**Green**	ATV	Clay	-0.092	0.082	0.009	-0.085	-0.009
*Coyote_1	**Green**	ATV	Granite	-0.050	0.033	-0.031	-0.001	-0.023
Faultline_2	**Green**	Road	Clay	-0.020	0.046	-0.026	-0.044	-0.019
*Sage	**Green**	Road	Granite	-0.007	0.031	-0.026	-0.001	-0.008
OK Corral_2	**Yellow**	Single Track	Clay	-0.009[a]	-0.009[a]	-0.079	-0.001	-0.022
*Mystic	**Yellow**	Single Track	Granite	-0.023	0.010	-0.021	-0.016	-0.002
*Backsprings_2	**Yellow**	ATV	Clay	-0.016	-0.014	0.065	-0.005	-0.012
Coyote_2	**Yellow**	ATV	Granite	0.066	-0.018	0.029	-0.016[a]	-0.016[a]
Faultline_1	**Yellow**	Road	Clay	-0.050	0.021	-0.031	-0.052	-0.041
North Canyon	**Yellow**	Road	Granite	0.001	0.035	0.079	-0.021	-0.060
Psych Hill	**Red**	Single Track	Clay	N/A	-0.171	-0.040[a]	-0.040[a]	-0.040[a]
*Donnybrook_1	**Red**	Single Track	Granite	-0.023	0.008	-0.170	-0.055	-0.038
Backsprings_1	**Red**	ATV	Clay	-0.226	0.191	-0.173	0.000	-0.006
*Badger	**Red**	ATV	Granite	0.011	0.006	-0.170	-0.036	-0.038
Rancho	**Red**	Road	Clay	-0.013	-0.025	1.286	-0.031	-0.023
*Lake	**Red**	Road	Granite	0.013	-0.020	0.022	-0.039	-0.083

Notes for Table 3

*Sites with minor corrections made to 2016-2017 values following GIS re-analysis

[a]A survey that followed an unsurveyed year and captured more than one year of change Topographic change was annualized and the incremental value was distributed to affected years.

Table 4: Annual average elevation change (m) summarized by year, sustainability rating, soil, trail type , and management. "NA" represents sites with no data for a particular category. Positive numbers indicate deposition and negative numbers indicate erosion.

2013-2014

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.02	-0.02	-0.03	-0.02	-0.01	-0.03	-0.01	-0.02	-0.04
Managed Sites	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unmanaged Sites	-0.02	-0.02	-0.03	-0.02	-0.01	-0.03	-0.01	-0.02	-0.04

2014-2015

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.01	-0.02	-0.03
Managed Sites	NA	NA	NA	NA	NA	NA	NA	NA	NA
Unmanaged Sites	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	-0.01	-0.02	-0.03

2015-2016

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.03	-0.09	0.01	-0.02	-0.03	-0.03	-0.04	-0.05	0.00
Managed Sites	-0.02	-0.07	0.07	0.01	0.04	-0.07	NA	-0.03	0.02
Unmanaged Sites	-0.03	-0.10	0.00	-0.02	-0.05	-0.02	-0.04	-0.06	0.00

2016-2017

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	0.01	0.00	0.00	0.04	0.02	0.01	-0.02	0.05	0.01
Managed Sites	0.02	0.04	0.00	0.03	0.04	0.01	-0.01	0.04	0.01
Unmanaged Sites	0.00	-0.08	0.02	0.04	0.00	0.00	-0.03	0.08	0.03

2017-2018

Averages	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.03	-0.05	-0.01	-0.03	-0.06	0.00	-0.01	-0.05	-0.01
Managed Sites	0.00	0.00	0.01	-0.03	-0.02	0.01	-0.02	0.00	0.00
Unmanaged Sites	-0.06	-0.12	-0.04	-0.03	-0.10	-0.01	-0.01	-0.16	-0.04

Topographic change is more variable starting in 2016 (Fig. 4). At that time, the analysis areas at each site were expanded through the use of photogrammetry, and site management increased. According to a one-way ANOVA (with unequal variance), mean elevation changes do not differ through time, (df = 4/39.4, F=1.2, P=0.3), despite the great differences in annual precipitation (Fig. 4).

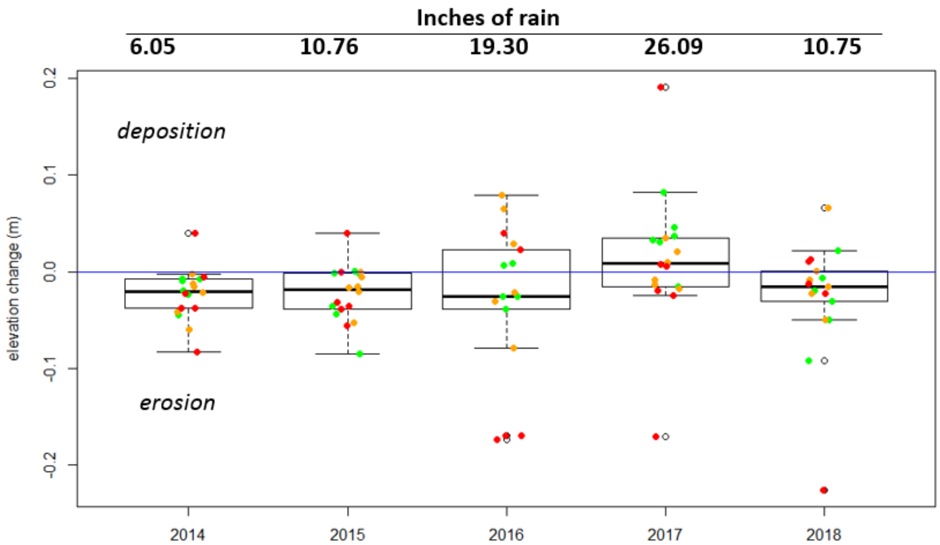

Figure 4. Annual average elevation change for five years of assessment with corresponding annual precipitation. Dots show individual sites colored by sustainability index (Green, yellow, red). ANOVA p= 0.3.

Table 5 summarizes the results over the 5 years as annual averages parsed by soil type, vehicle usage, classification, and whether or not the site was managed. When managed and unmanaged sites are examined together, a one-way ANOVA (with unequal variance) does not distinguish among the annual erosion rates of red, yellow and green rated trails (df = 2/51.7, F=1.2, P=0.3). Figure 5 illustrates the similarity in median values among the three trail classification levels, while table 5 reports the similarity in mean values. The standard deviation of red sites (0.09 m/yr) is twice that of yellow (0.04 m/yr) and green sites (0.04m/yr). A Lavene's test for homogeneity of variance shows that red site annual variability is significantly higher than annual variability of other sustainability categories (df=2, F=5.3, p=0.007). Extreme annual values in red sites are more often erosional than depositional (Fig. 5).

When five-year cumulative elevation change is computed, red sites show more erosion than the other two sustainability categories (Fig. 5). A one-way ANOVA (with unequal variance) indicates that red sites are significantly different from the other sites (df = 2/7.1, F=5.3, P=0.04), with red sites showing 0.13 m more erosion than green sites over the five-year span.

Table 5: Five-year average annual elevation changes (m) for all study sites. Other notes as in Table 4.

2013-2018 *Averages*	Overall	red	yellow	green	clay	granite	ST	ATV	Road
All Sites	-0.02	-0.04	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.01
Managed Sites	0.00	-0.01	0.02	0.00	0.02	-0.02	-0.01	0.00	0.01
Unmanaged Sites	-0.03	-0.07	-0.01	-0.01	-0.04	-0.02	-0.02	-0.04	-0.01

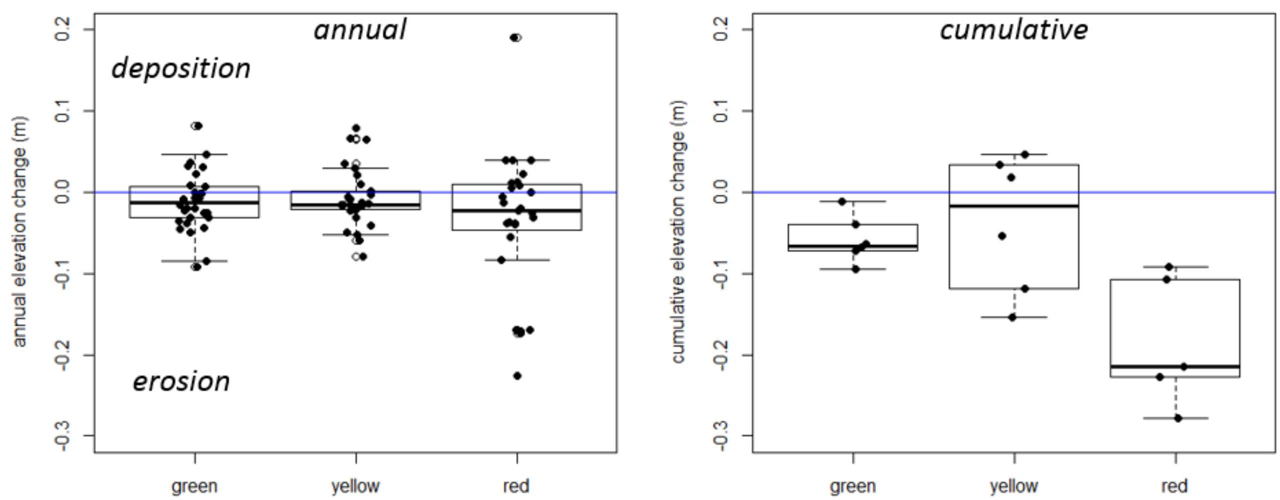

Figure 5: Boxplots of all study sites parsed by sustainability index. Left plot is annual elevation change (ANOVA p = 0.3). Right plot is five-year cumulative elevation change (ANOVA p=0.04).

Figure 6 shows that trail management decreases median annual erosion rates to nearly 0 m/yr in all sustainability groups. The positive impact of management is also supported by the average values for each year (Tables 4 and 5) and the median values in most years (Fig. 7). The extreme range of elevation changes noted in red sites is present in both managed and unmanaged sites (Fig. 6).

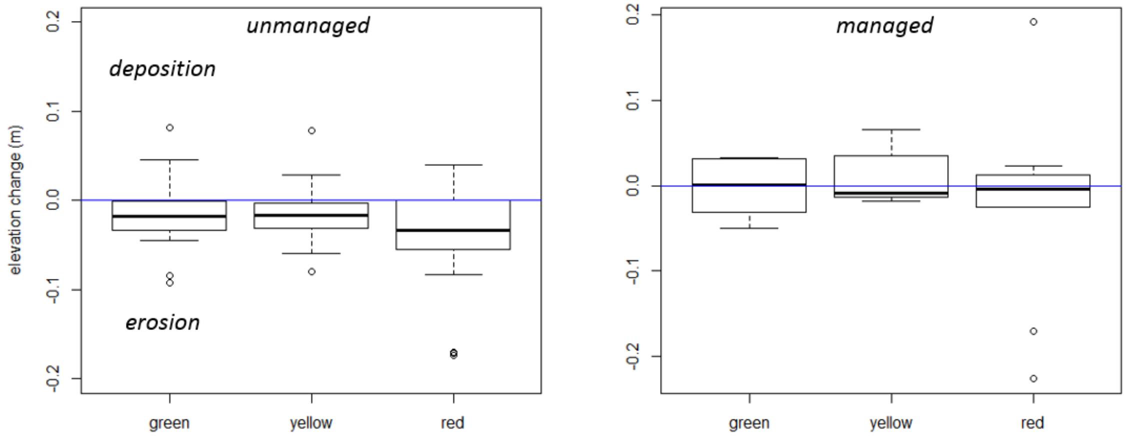

Figure 6: Boxplots of annual elevation change for all sites separated by management activity and sustainability index.

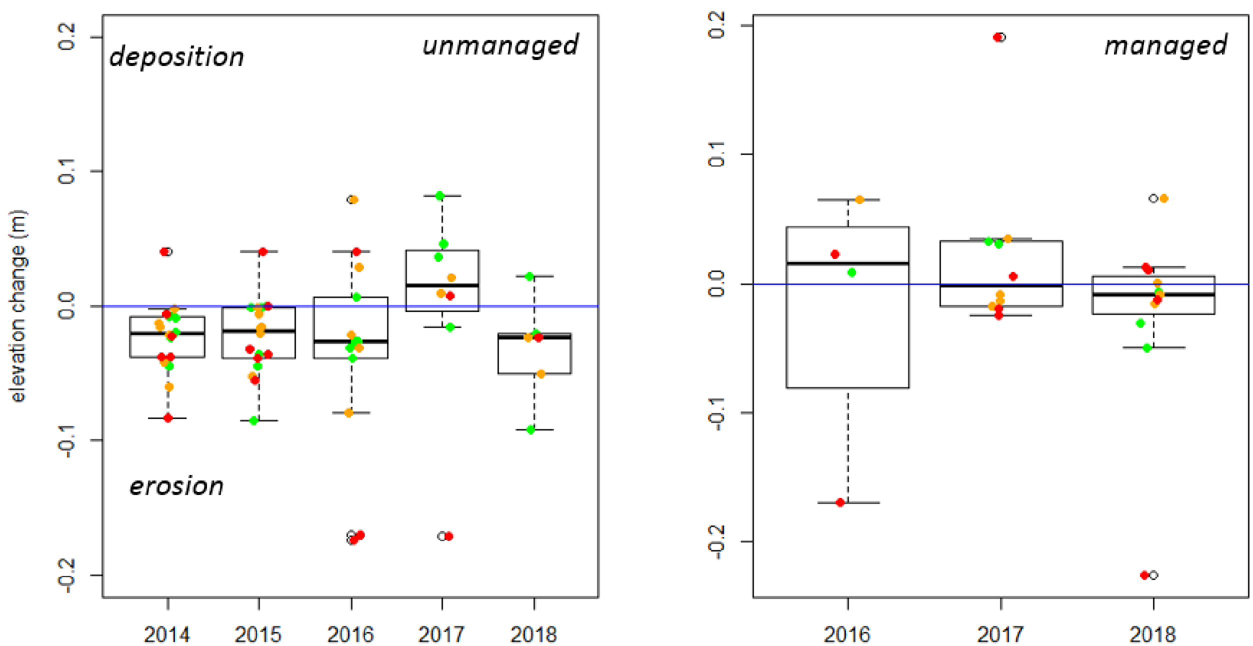

Figure 7: Boxplots of annual elevation change for all sites separated by year and management activity. Dots show individual sites colored by sustainability index (green, yellow, red).

Generally, substrate type (clay soils and granitic soils) did not influence median erosion rates (Fig. 8). While clay sites have more extreme values of erosion and deposition, the overall mean erosion rates are the same for both soil types (Table 5). As noted in previous figures, sustainability indices (red, yellow green) do not display a clear pattern (Fig. 8), even when parsed by soil type.

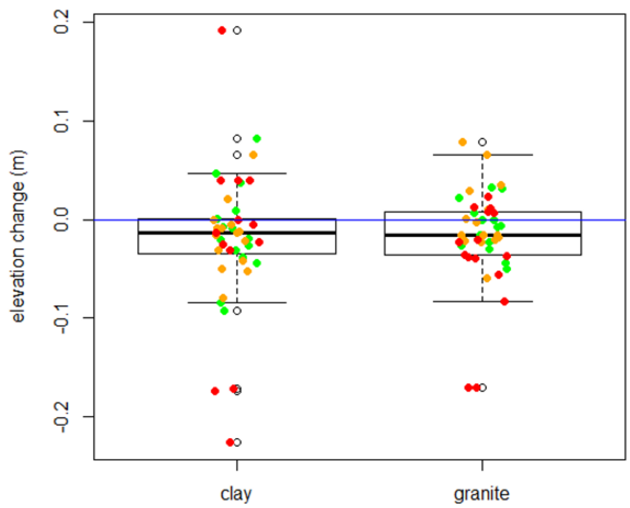

Figure 8: Boxplot of study sites divided by soil type. Dots show individual sites colored by sustainability index (green, yellow, red).

Annual erosion rates are plotted with respect to trail type (atv, road, single-track) in Figure 9. There is little difference between median erosion rates (Fig. 9) or mean rates (Table 5) among the three trail types. Managed sites had better results in both ATV and road categories, and little impact in single track sites (Table 5). As previously noted, the three sustainability levels (green, yellow, red) do not show the expected correspondence with low, medium, and high erosion rates, but red sites are notably more extreme than yellow or green.

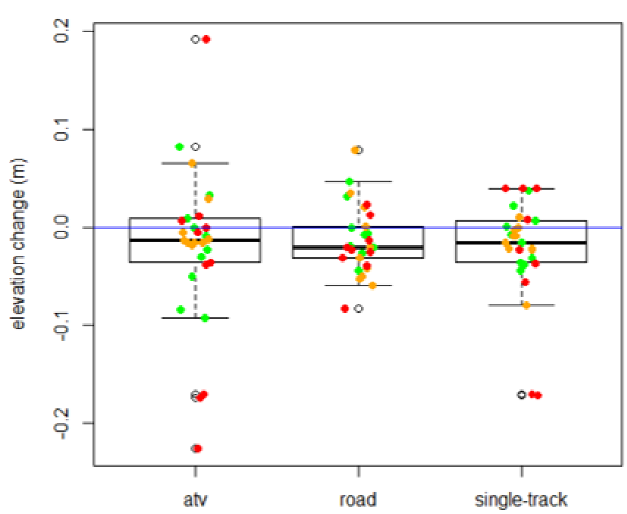

Figure 9: Boxplot of study sites divided by trail type. Dots show individual sites colored by sustainability index (Green, yellow, red).

4 Discussion

Five years of high-resolution surveys of 18 trail sites at Hollister Hills SVRA have produced the following general results.

1) We expected the Green, Yellow, Red trail sustainability index to correlate with low, intermediate, and high rates of trail erosion (CDPR 2008; HHSVRA 2012). While no statistical differences exist between the categories at the annual scale, red sites erode significantly more than green or red sites when the five-year cumulative effects are considered ($p<0.05$; Fig. 5). Green and yellow sites have similar annual and cumulative erosion rates.
2) The Universal Soil Loss Equation and other soil conservation models normally predict higher soil erosion rates with higher rainfall. Rainfall has varied from 6 inches to 26 inches during the study but the average annual erosion rate was lowest following the highest rain year (2017) when the net topographic response was 0.01 m of deposition (Fig. 4; Table 4).
3) Clay and granite sites erode at approximately equal rates when averaged over several years (Fig. 8).
4) Trail type did not highly influence the time-averaged erosion rates (Fig. 9; Table 4).
5) Trail management that mainly consists of replacing the sidecast berm back into the trail tread is an effective strategy for improving trail sustainability (Table 4; Table 5; Figs. 6 and 7).

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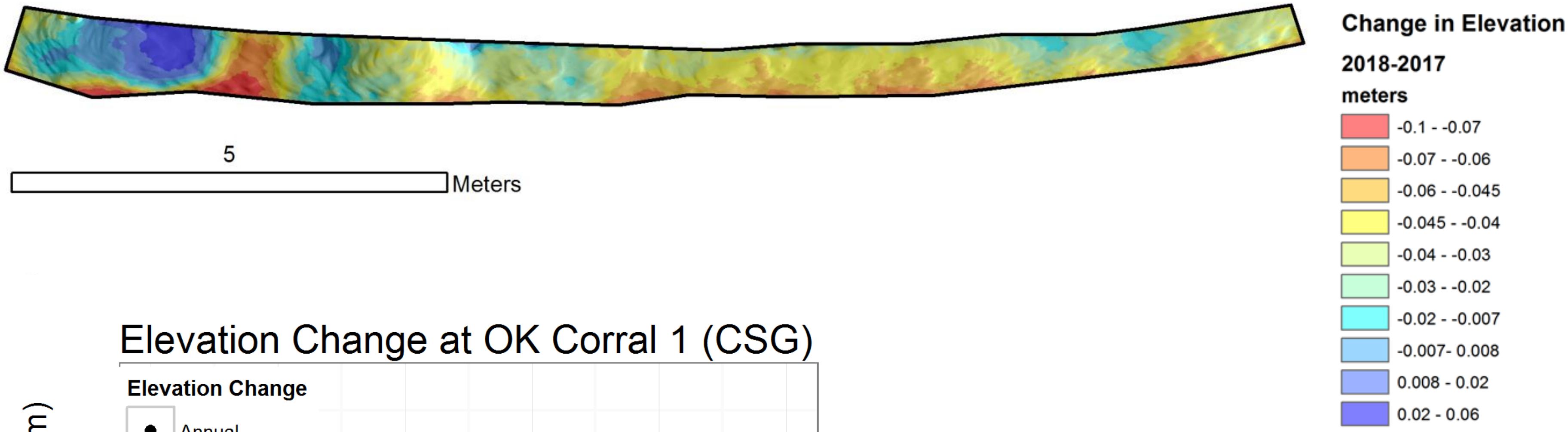
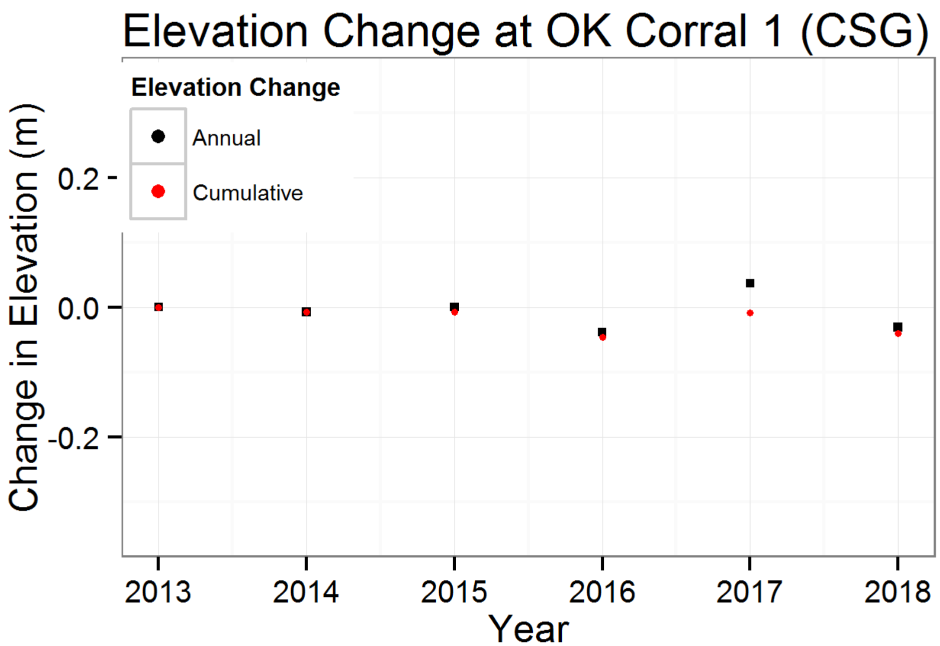
6 Appendix A

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

Hillshades of each site are colored with respect to 2018 annual topographic change. Positive values indicate sediment deposition and negative values indicate erosion.

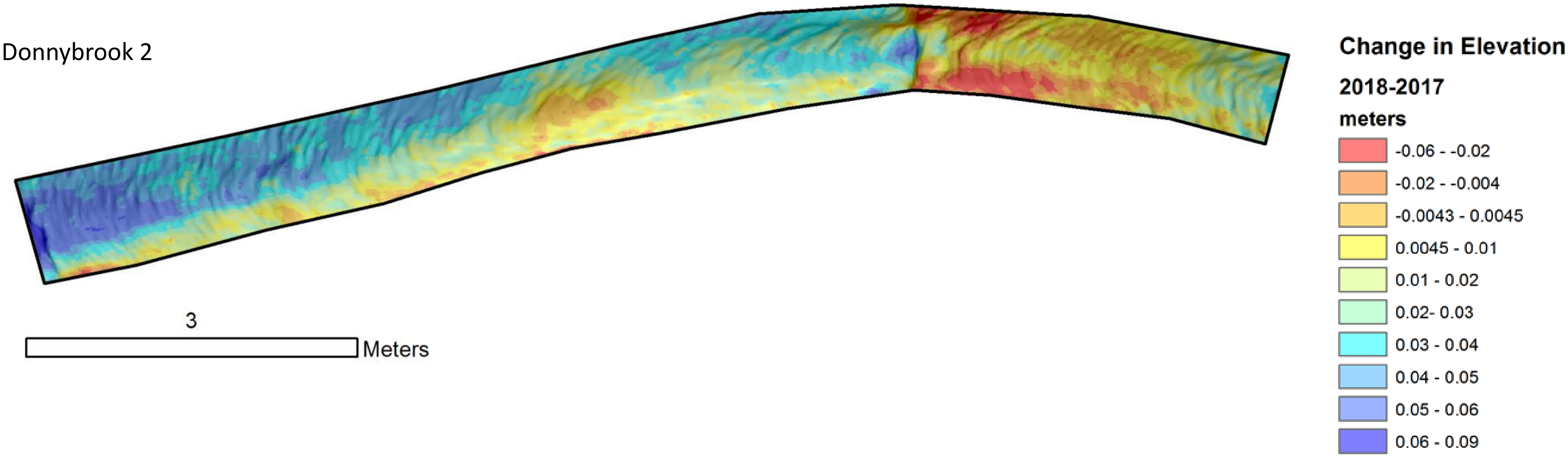
OK Corral 1

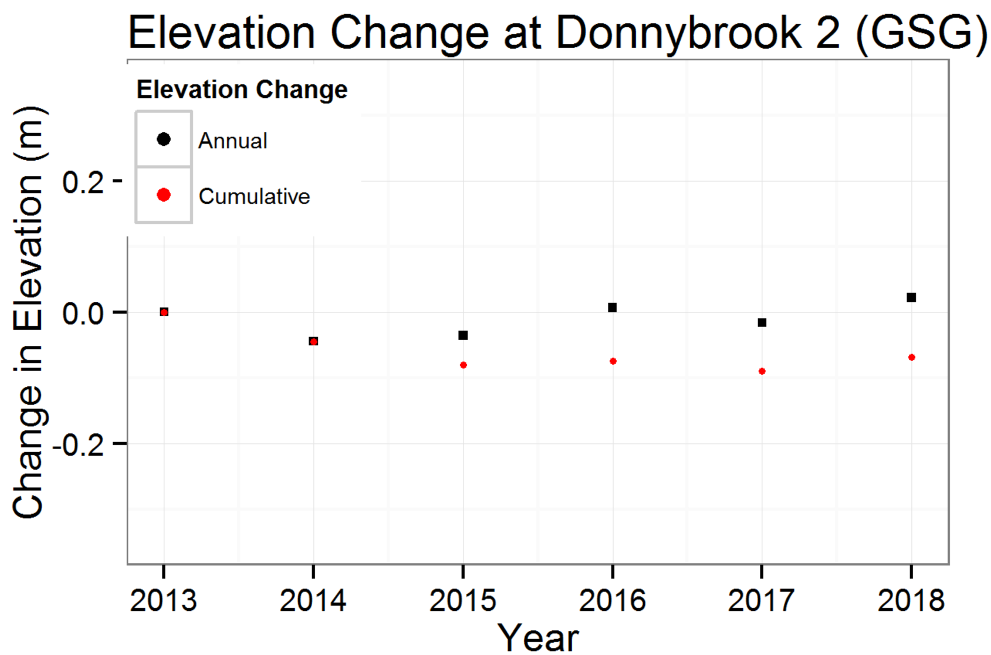




2013-2018 Elelvation Change (m)		OK Corral 1 (CSG)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.040	-0.008	0.005

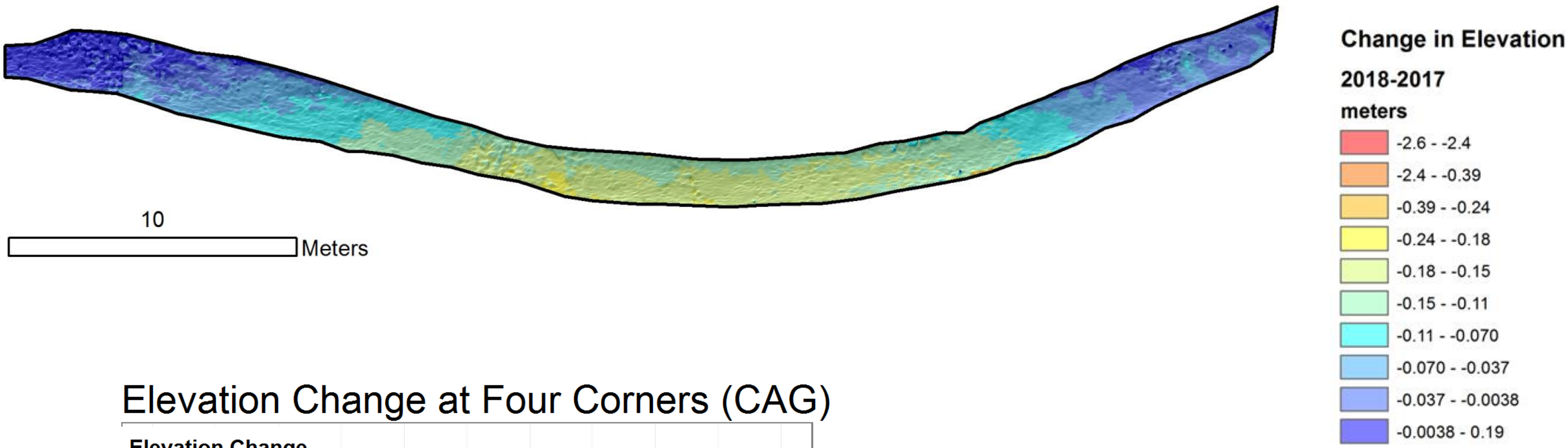
Donnybrook 2

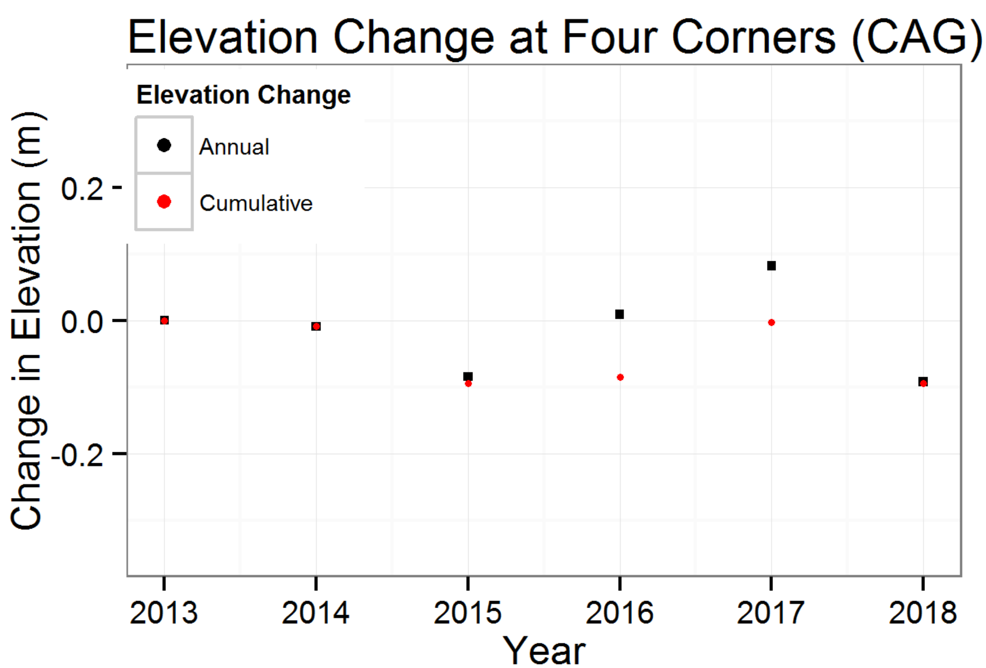




2013-2018 Elelvation Change (m)		Donnybrook 2 (GSG)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.068	-0.014	0.006

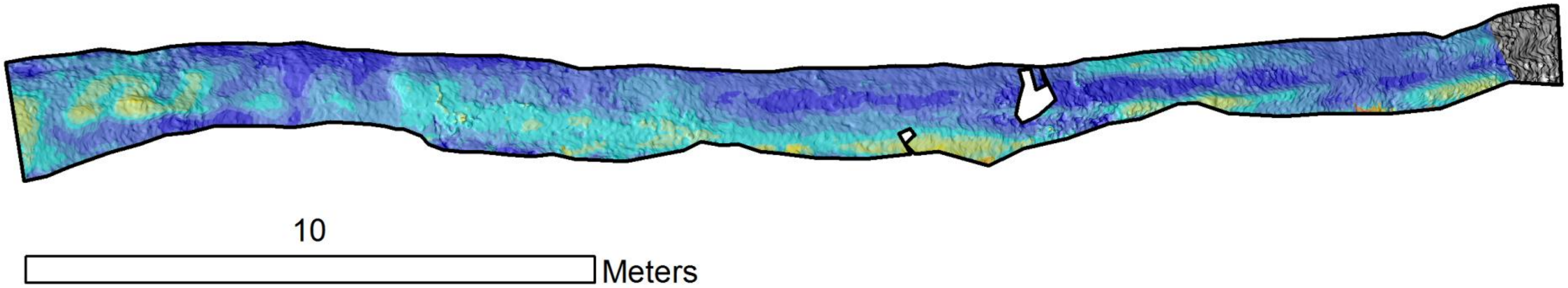
Four Corners

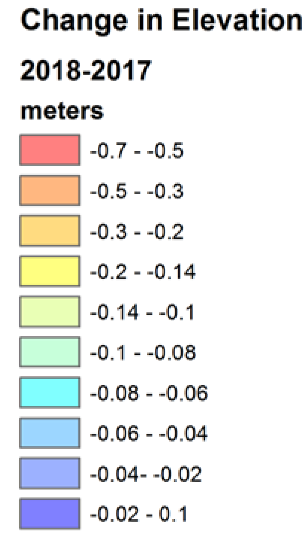


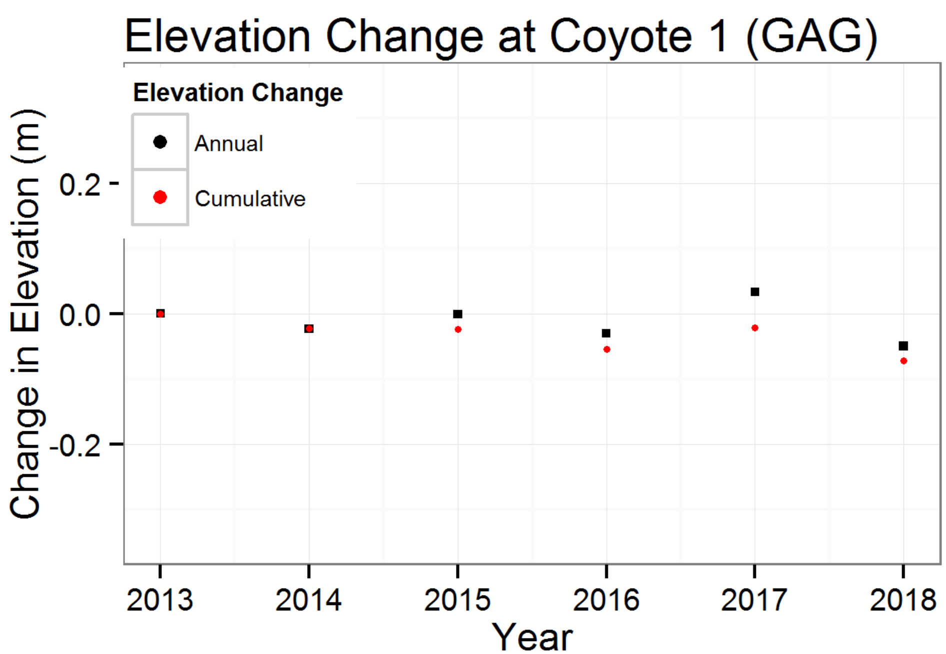


2013-2018 Elelvation Change (m)		Four Corners (CAG)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.095	-0.019	0.006

Coyote 1

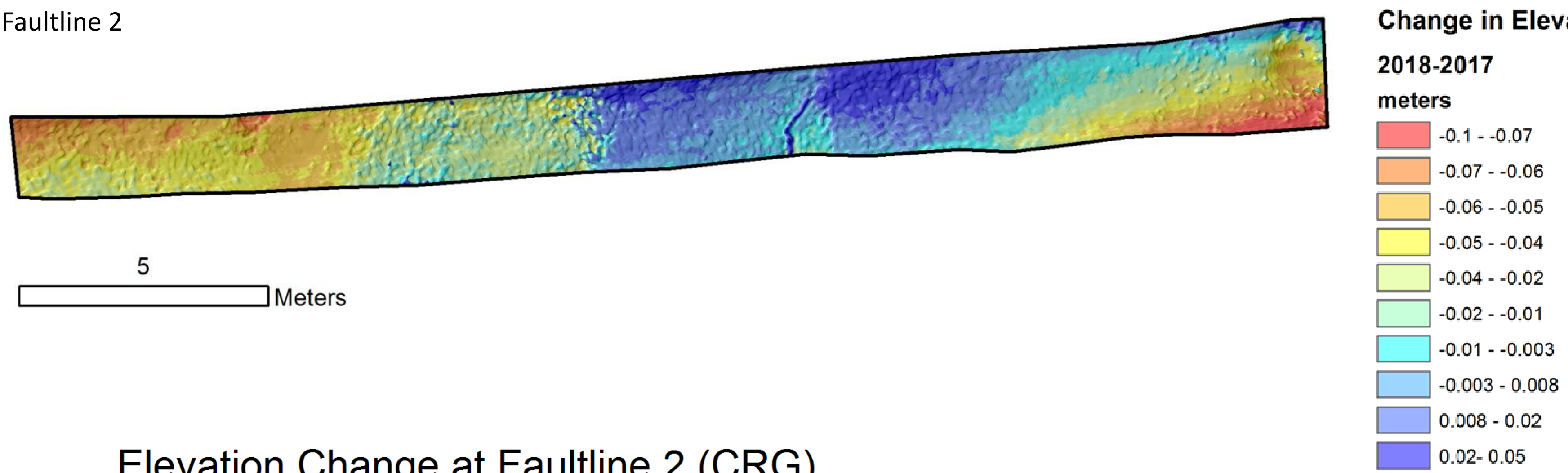


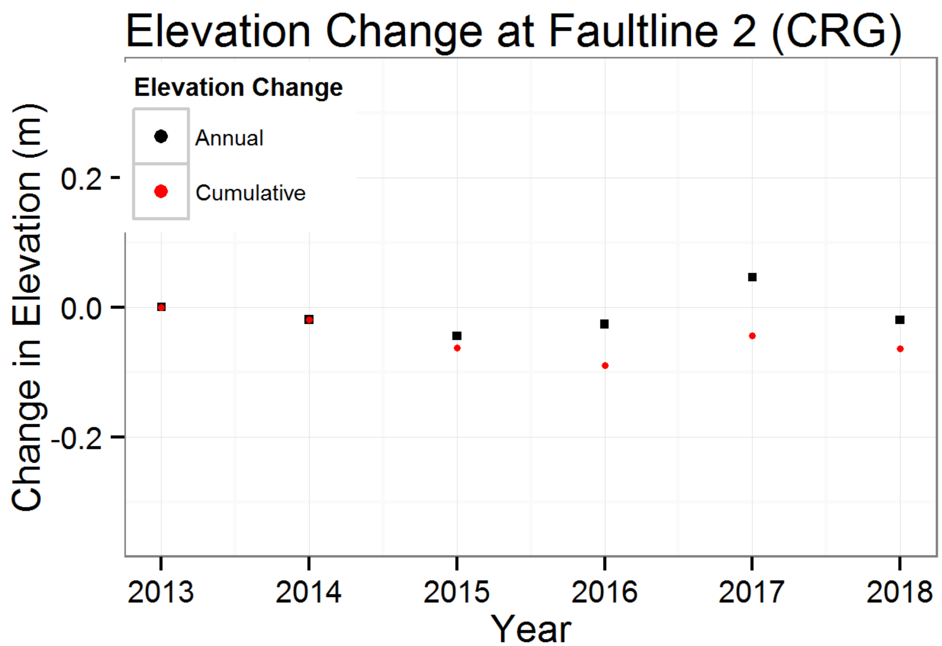




2013-2018 Elelvation Change (m)		Coyote 1 (GAG)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.072	-0.014	0.003

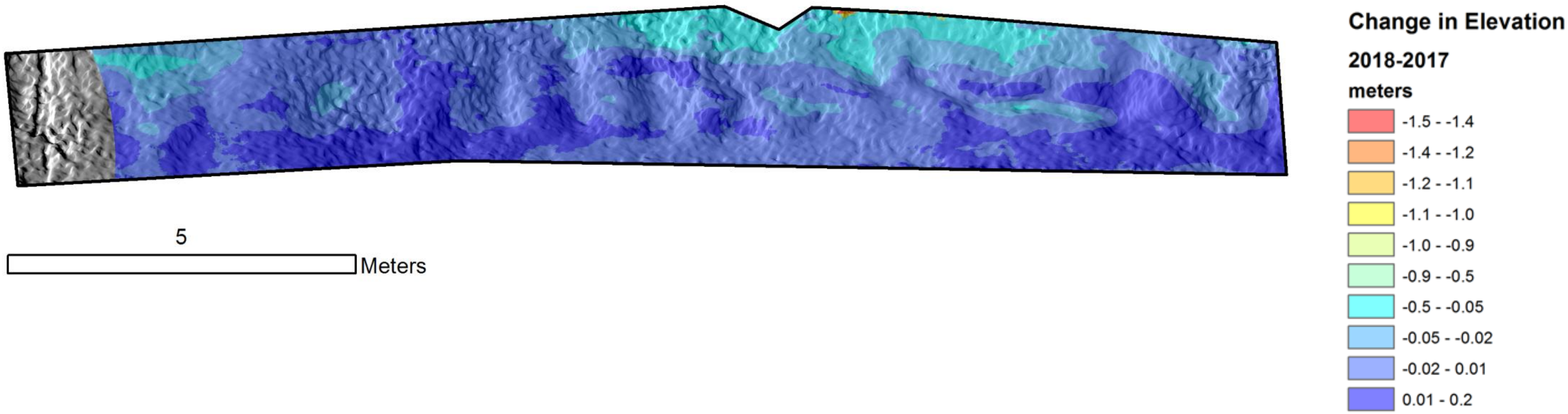
Faultline 2

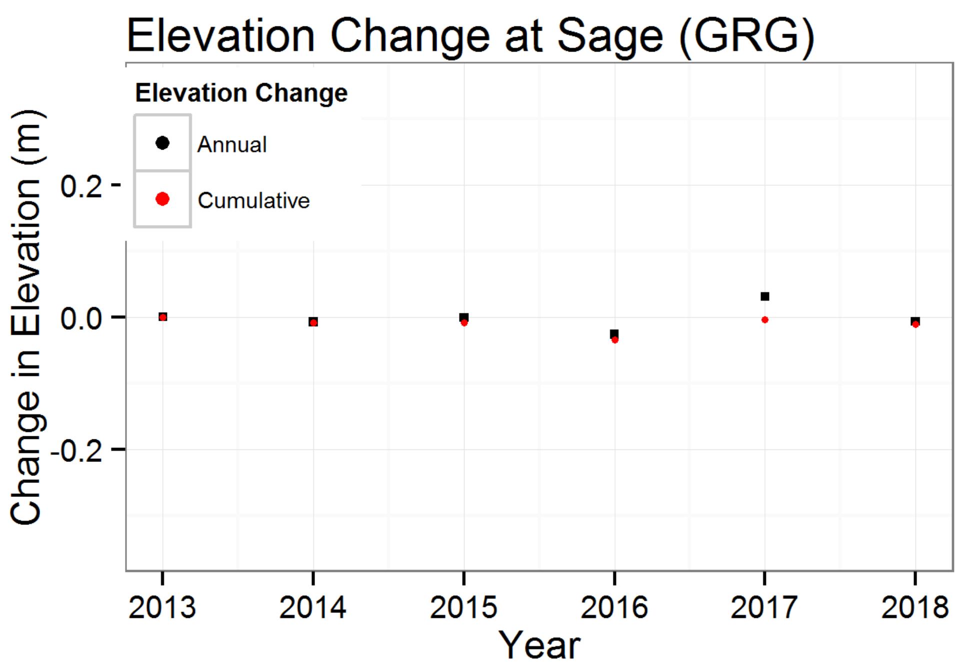




2013-2018 Elelvation Change (m)		Faultline 2 (CRG)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.064	-0.013	0.004

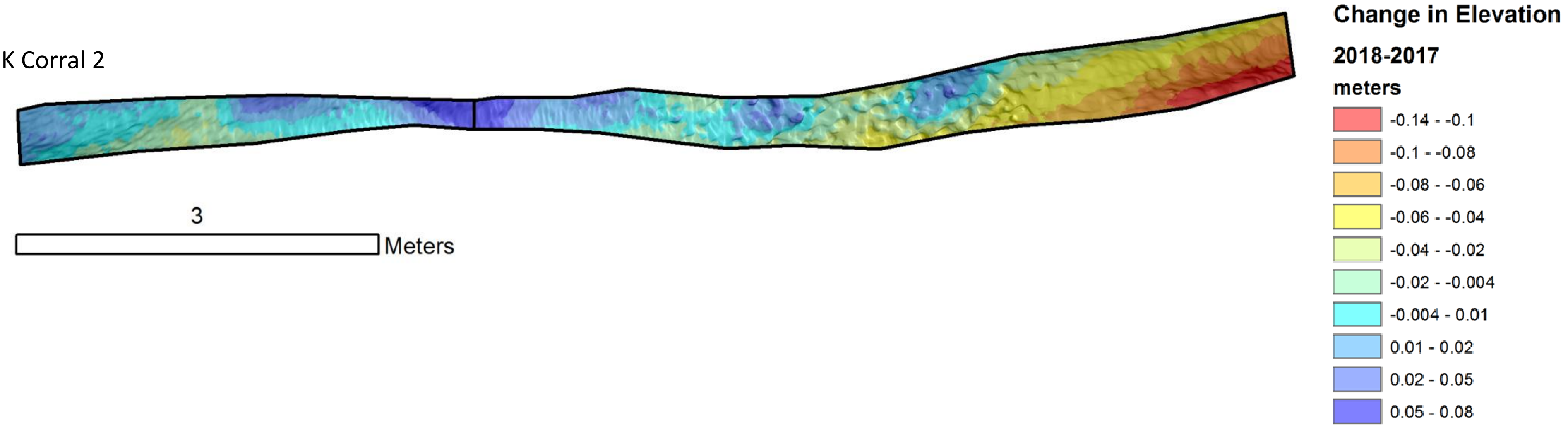
Sage

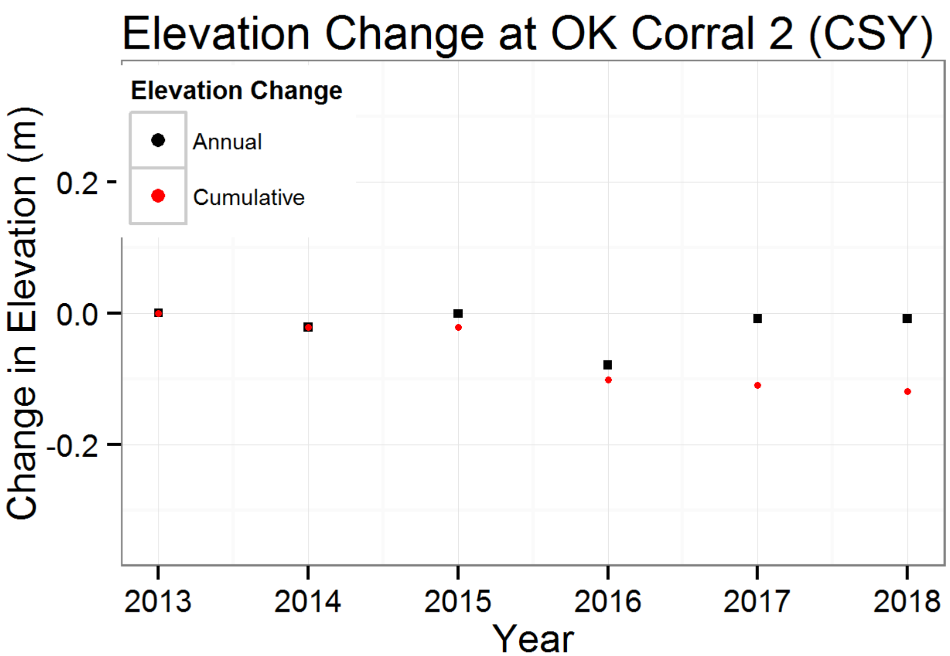




2013-2018 Elelvation Change (m)		Sage (GRG)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.011	-0.002	0.004

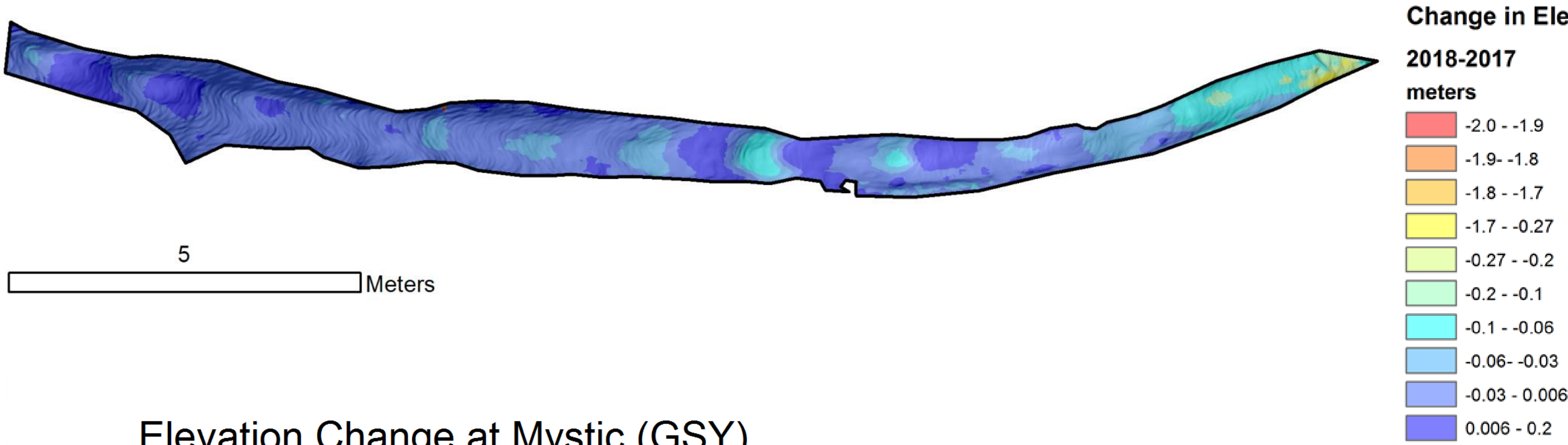
OK Corral 2

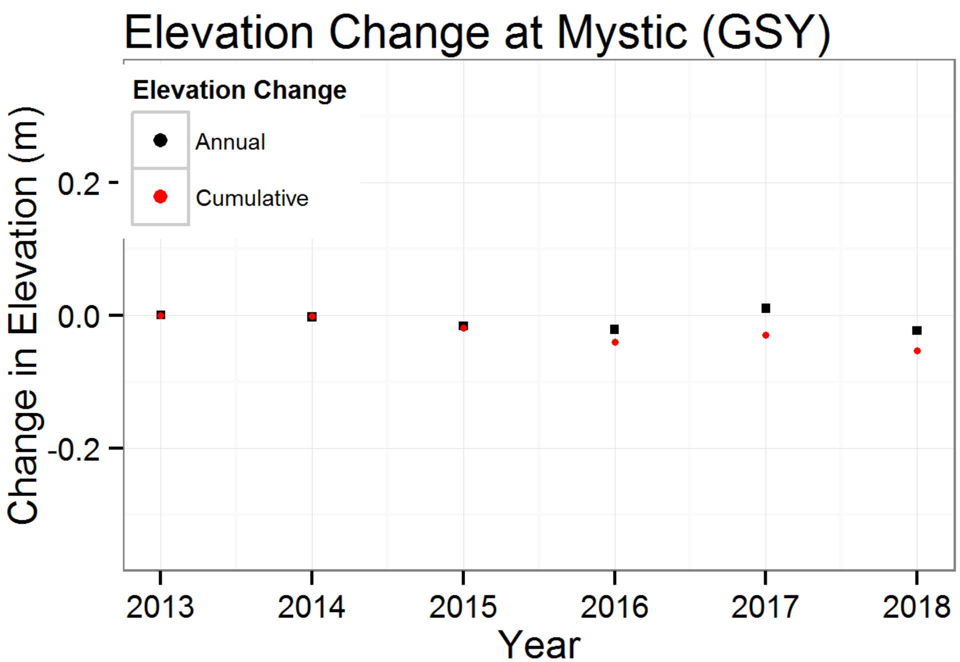




2013-2018 Elelvation Change (m)		OK Corral 2 (CSY)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.120	-0.024	0.003

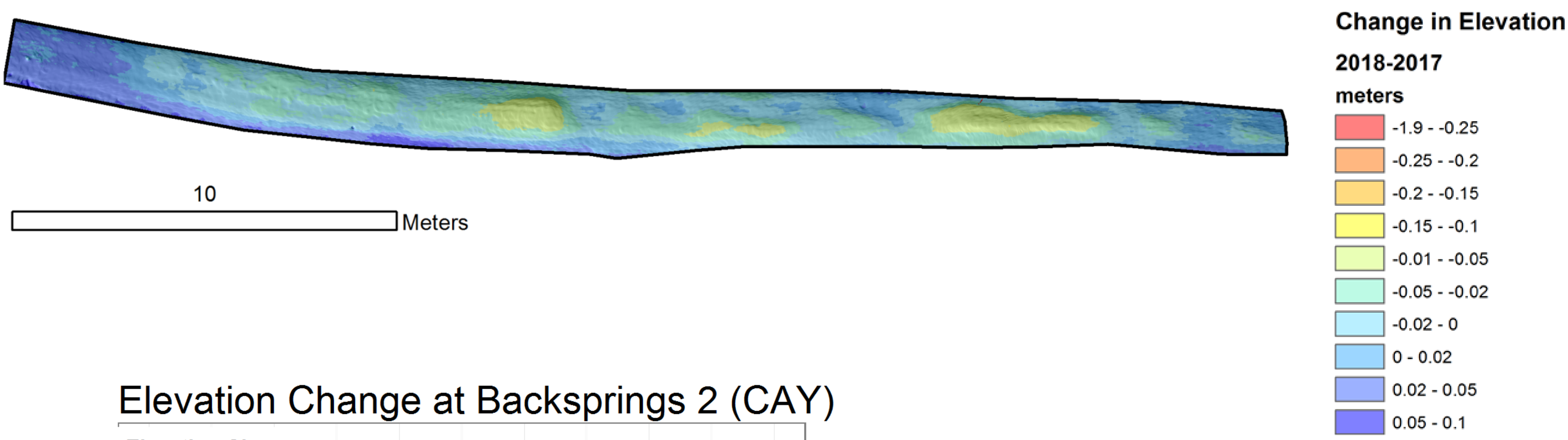
Mystic

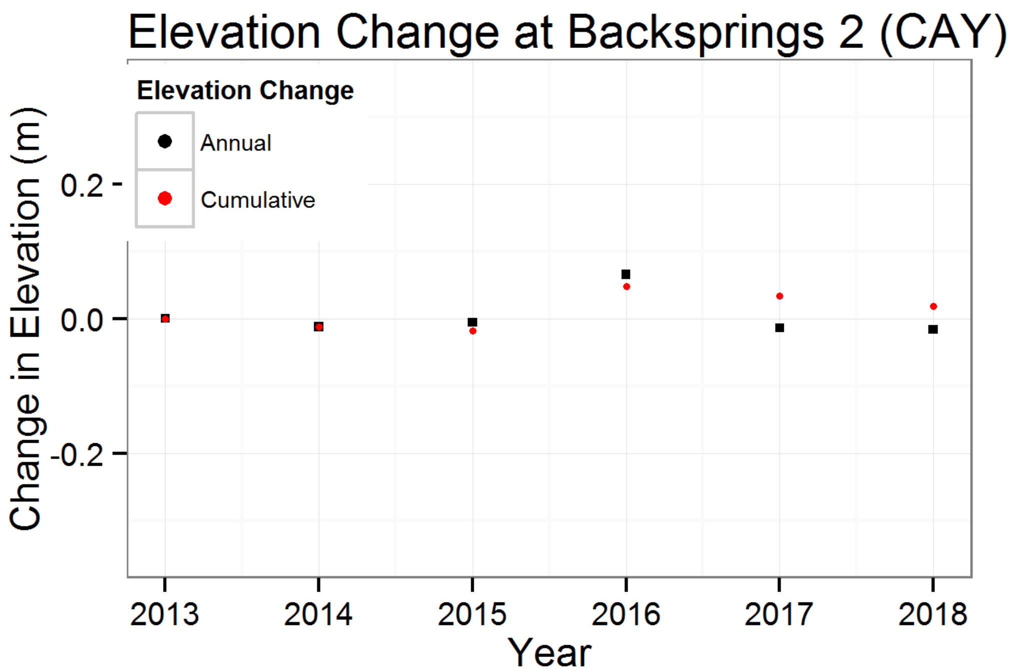




2013-2018 Elelvation Change (m)		Mystic (GSY)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.053	-0.011	0.005

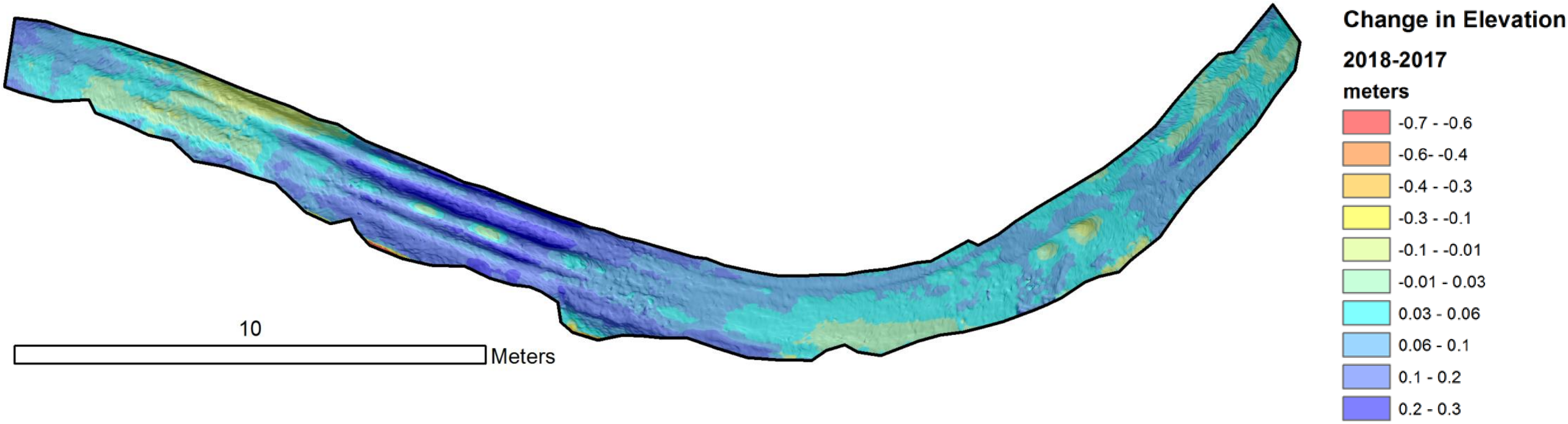
Backsprings 2

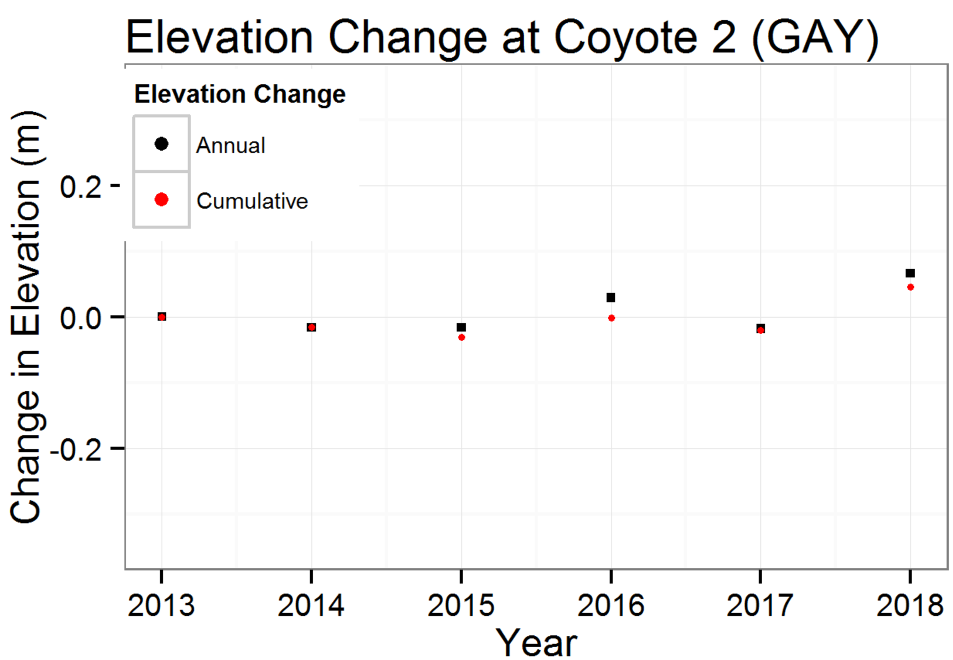




2013-2018 Elelvation Change (m)		Backsprings 2 (CAY)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
0.018	0.004	0.003

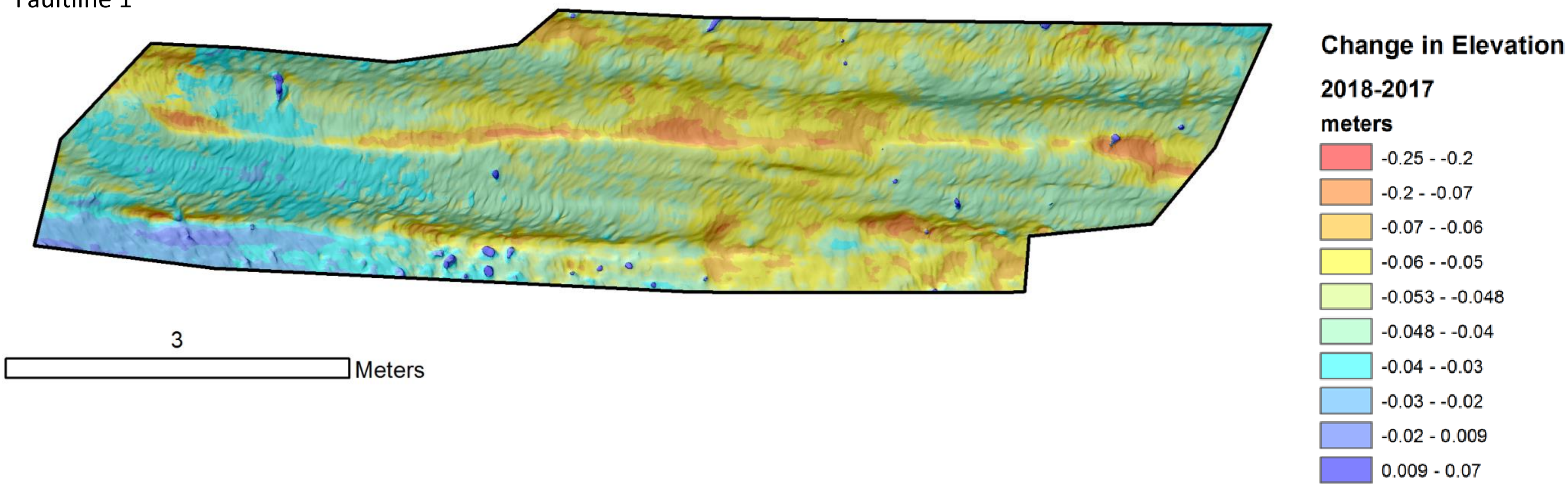
Coyote 2

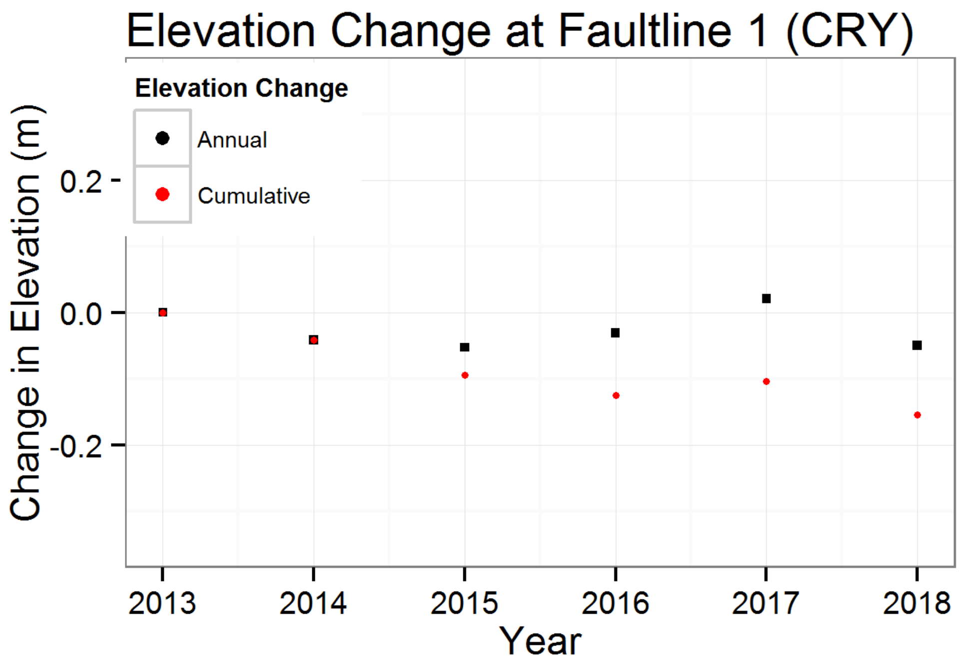




*2013-2018 Elelvation Change (m)		Coyote 2 (GAY)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
0.046	0.011	0.003

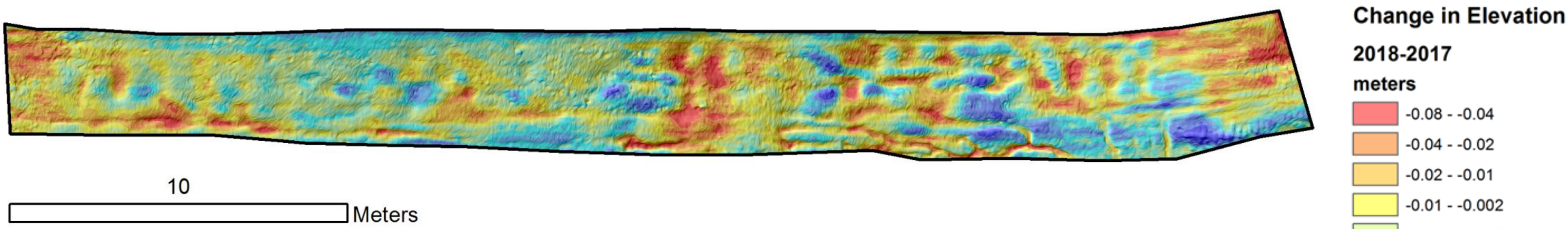
Faultline 1

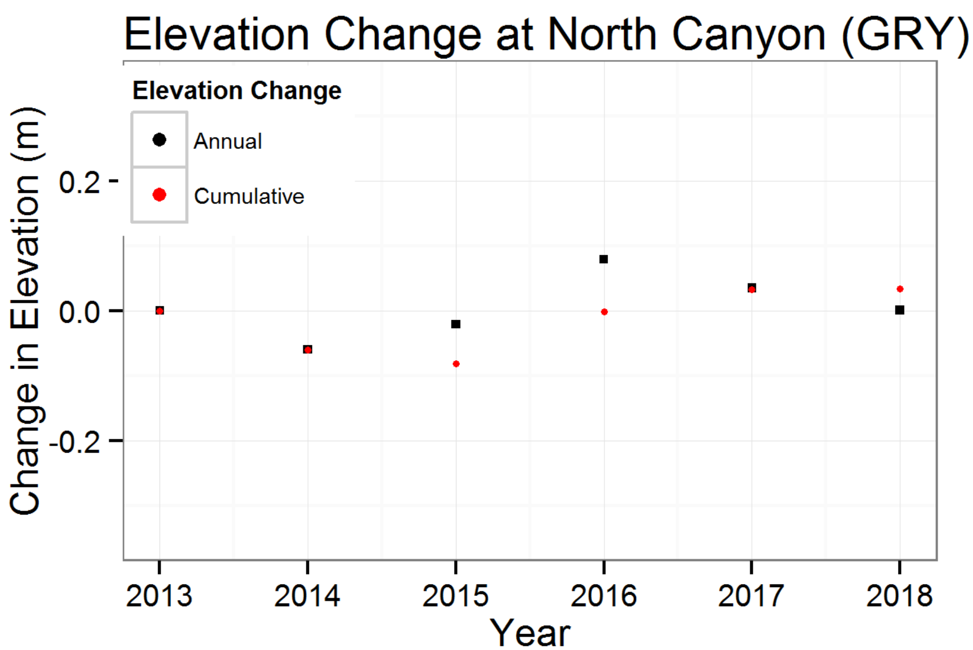




2013-2018 Elelvation Change (m)		Faultline 1 (CRY)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.154	-0.031	0.003

North Canyon

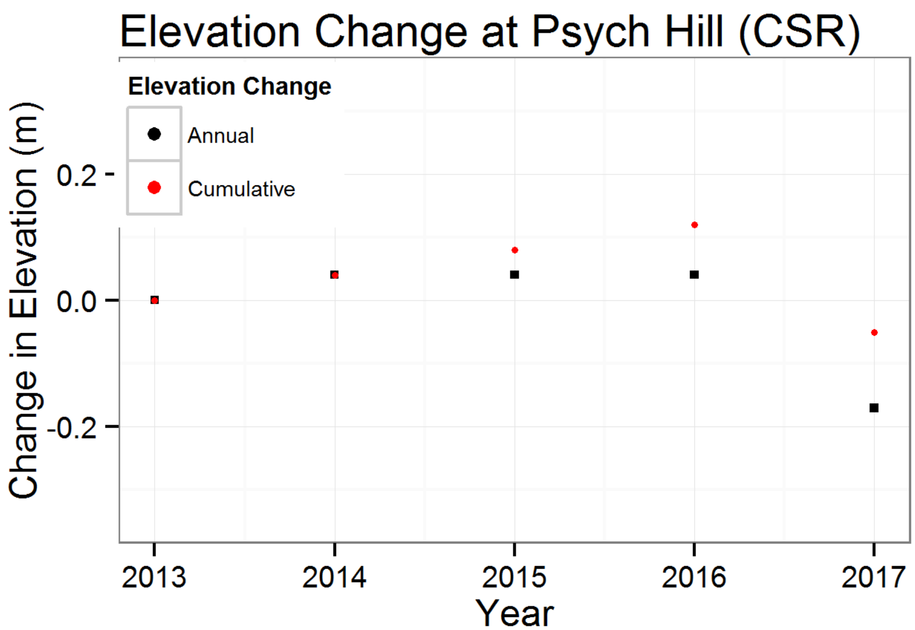




2013-2018 Elelvation Change (m)		North Canyon (GRY)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
0.034	0.007	0.004

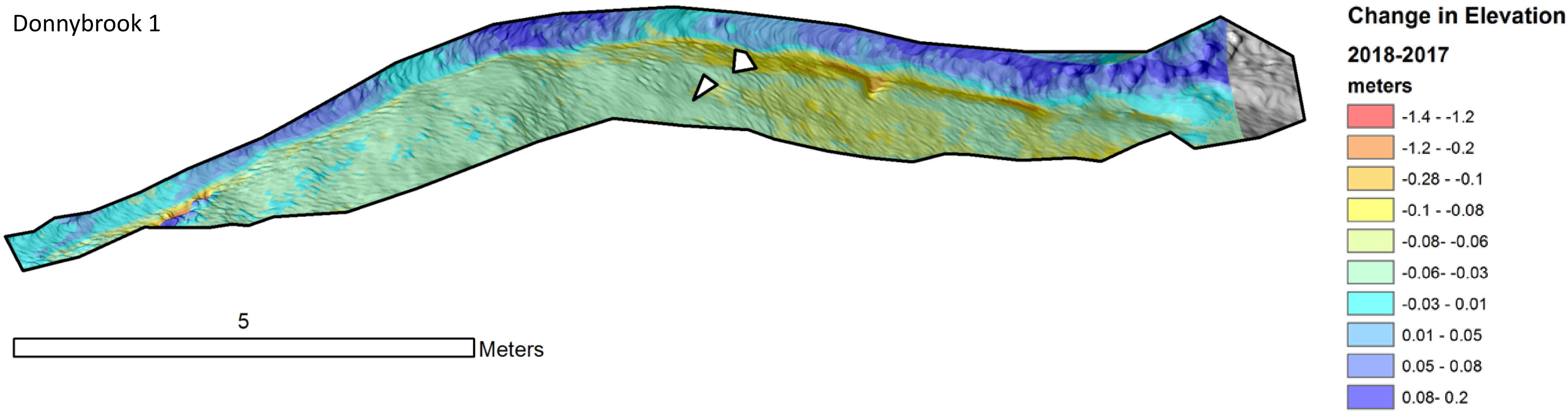
Psych Hill

Not surveyed in 2018

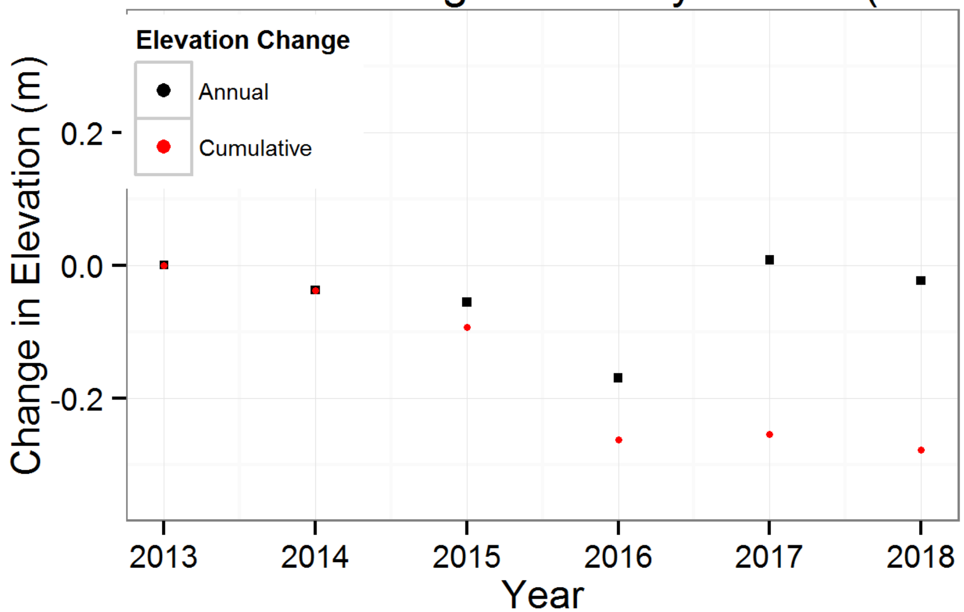


*2013-2018 Elelvation Change (m)		Psych Hill (CSR)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.051	-0.013	NA

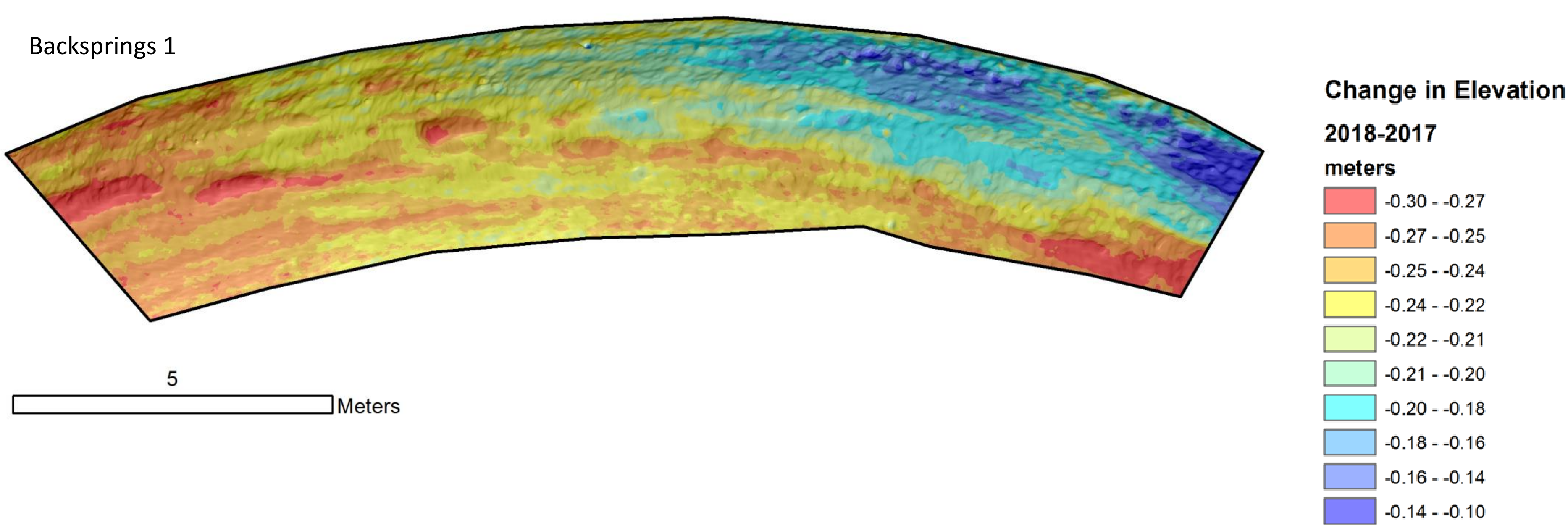
Donnybrook 1

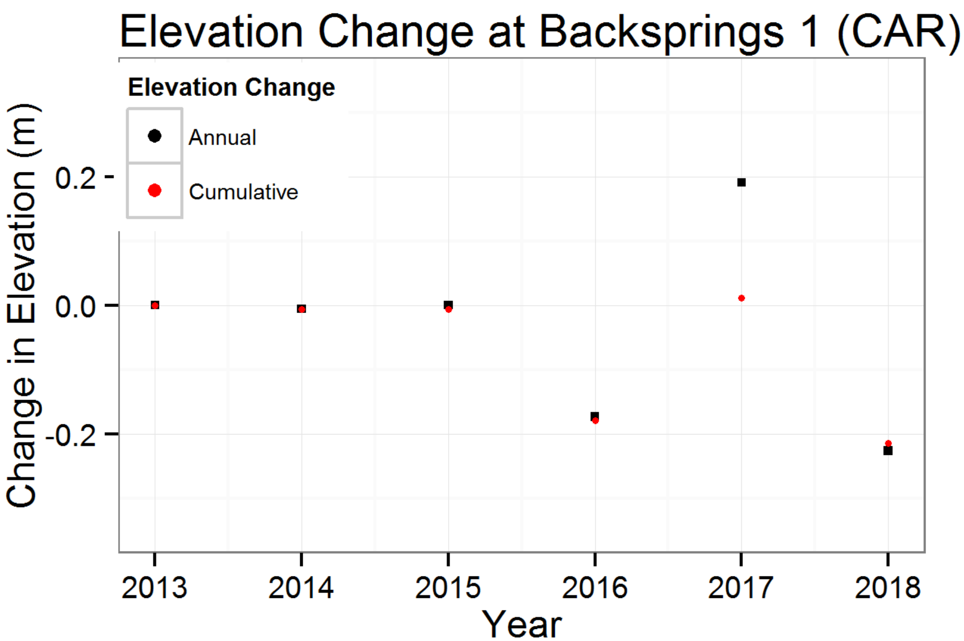


Elevation Change at Donnybrook 1 (GSR)



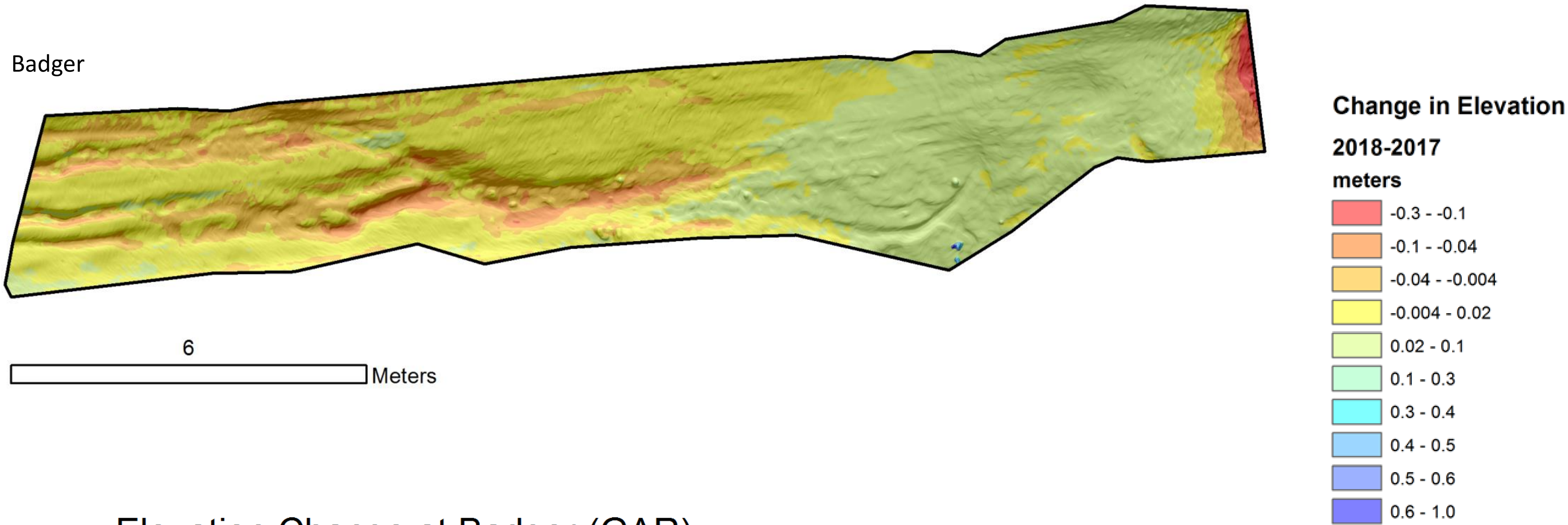
2013-2018 Elelvation Change (m)		Donnybrook 1 (GSR)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.278	-0.056	0.003

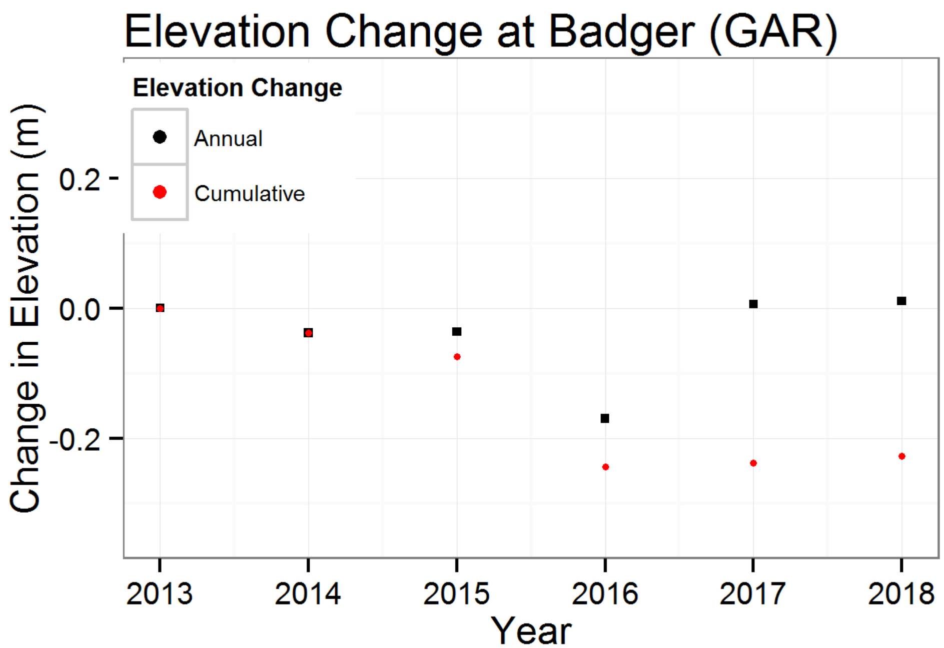




2013-2018 Elelvation Change (m)		Backsprings 1 (CAR)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.214	-0.043	0.004

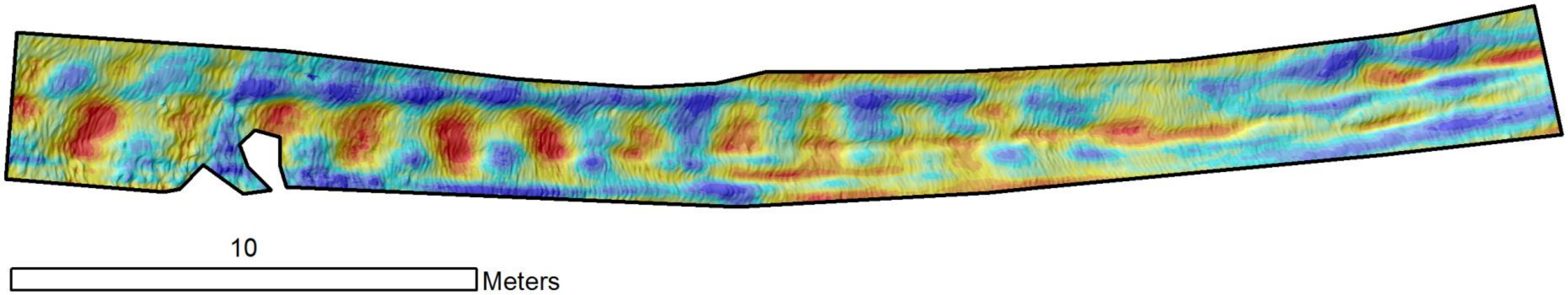
Badger

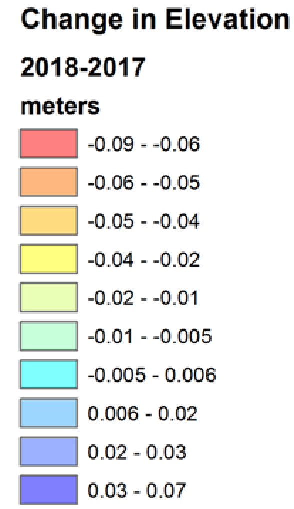


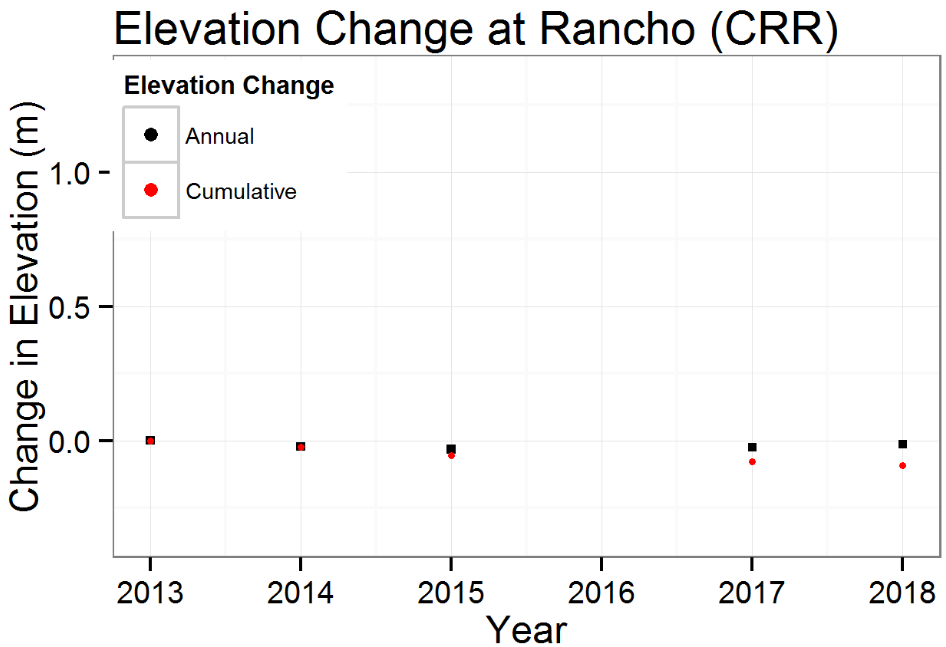


2013-2018 Elelvation Change (m)		Badger (GAR)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.227	-0.045	0.004

Rancho

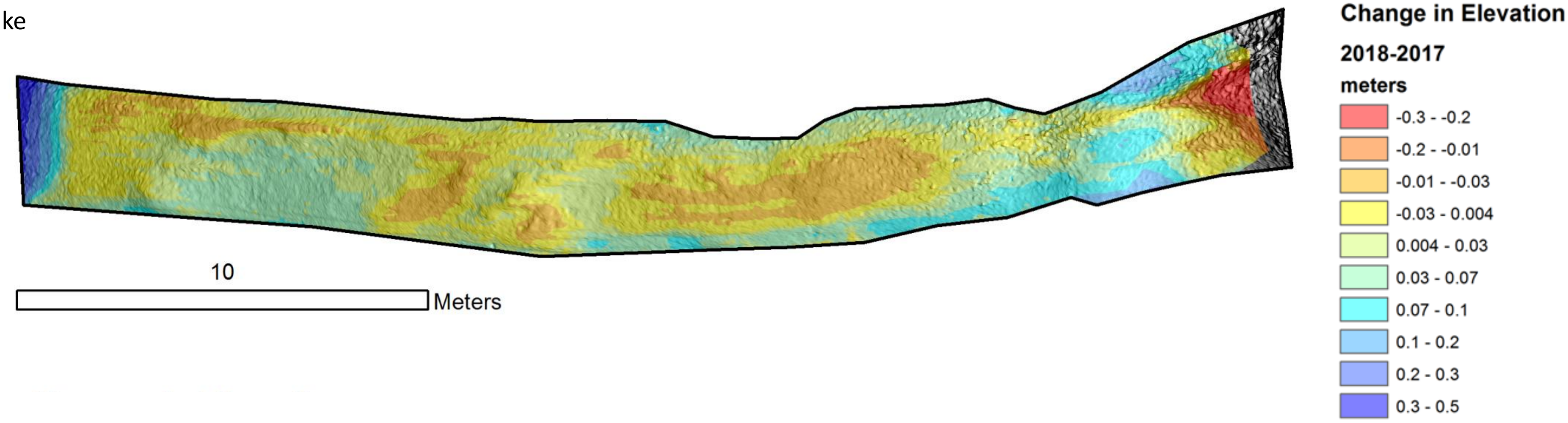


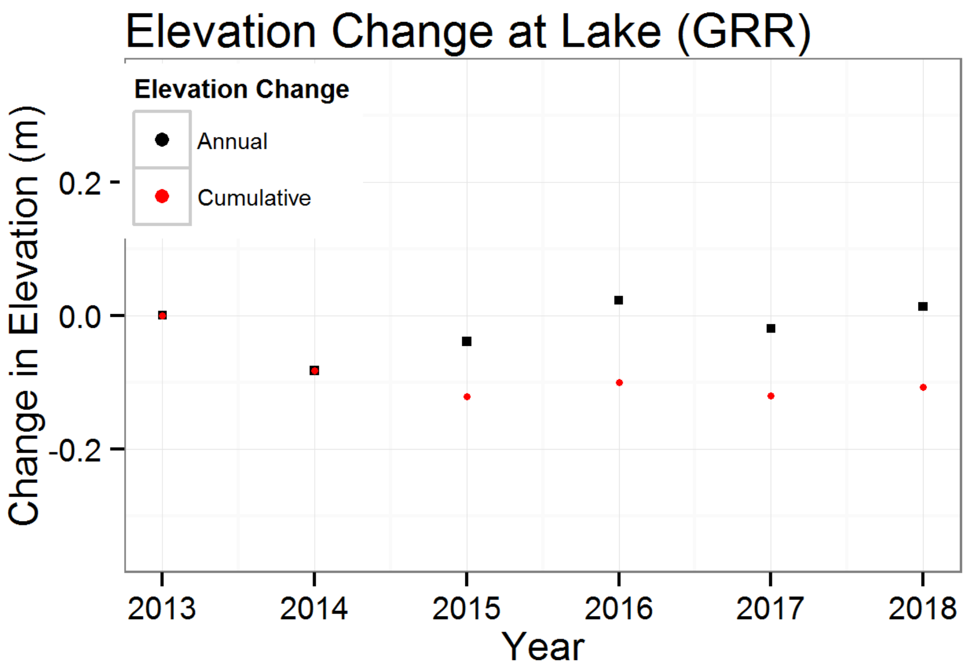




*2013-2018 Elelvation Change (m)		Rancho (CRR)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.092	-0.023	0.007

Lake





2013-2018 Elelvation Change (m)		Lake (GRR)
Cumulative change	Annual Average	2018 GCP Z RMSE (m)
-0.107	-0.021	0.003