Assessing Debris Flow Hazards in the Aftermath of the 2025 Eaton Wildfire: UAV Lidar-Based Assessment of Debris Volumes Delivered to Basins during the Presidents' Weekend Storm (Feb. 13-15, 2025)

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March 6, 2025

Summary

In the aftermath of the January 2025 Eaton and Palisades wildfires in Los Angeles County, assessing the capacities of debris basins is critical for forecasting potential hazards associated with upcoming rain events. This report provides a low-cost, efficient assessment of debris basin capacities using UAV-based lidar surveys to provide high-resolution topographic data. We conducted surveys of 14 debris basins in the Eaton Fire area to quantify the change in capacity following the Presidents' Day weekend storm event (February 13-14, 2025). For some basins, we conducted repeat surveys following the storm to assess if significant dewatering had occurred (i.e., to better measure debris volumes vs. water volumes). We found that the storm delivered approximately 480,000 cubic yards of debris to the 14 surveyed basins, filling the basins to amounts ranging from 12 - 59% of their design capacities. The results from this study are intended to support emergency management agencies by (i) prioritizing debris basin cleanouts, (ii) calibrating and validating debris flow models for the burned catchments, and (iii) forecasting potential debris flow risks for upcoming storm events.

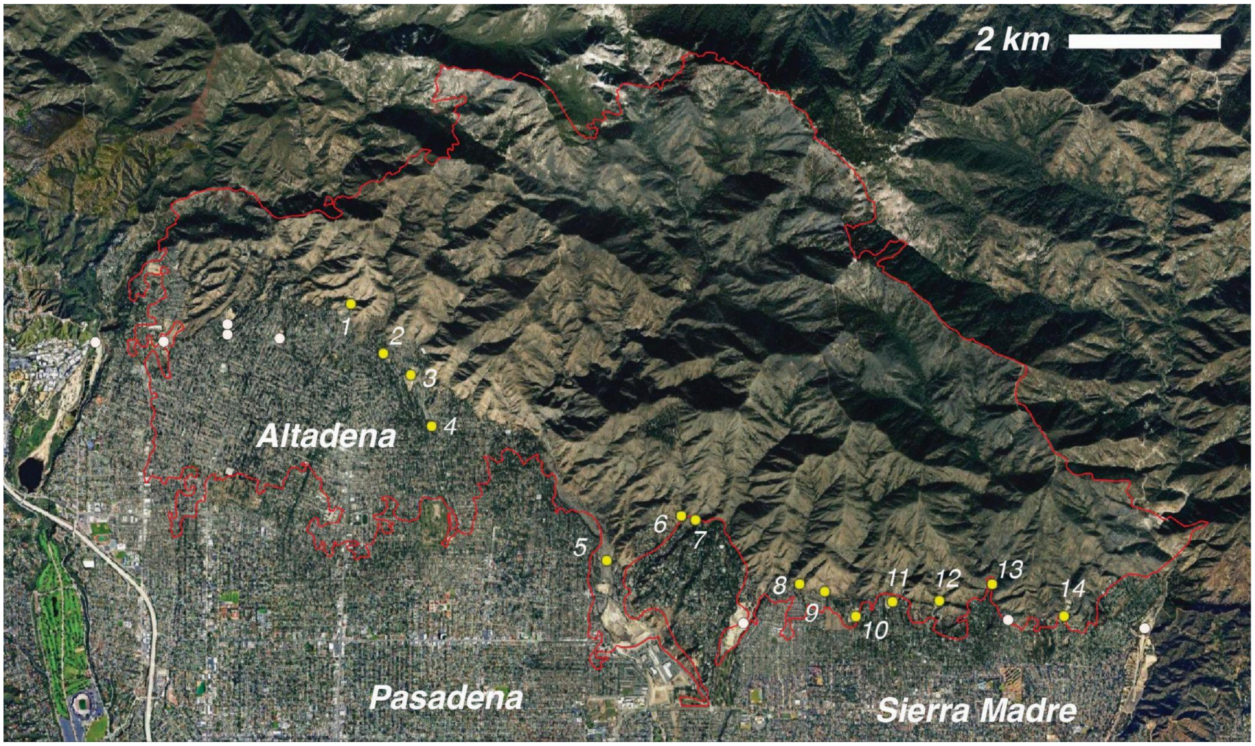

Figure 1: Eaton fire perimeter (red outline) with locations of LA County debris basins (white and yellow points). Basins surveyed by UAV are denoted in yellow. (1) Devonwood, (2) Las Flores, (3) Rubio, (4) Gooseberry, (5) Eaton Wash, (6) Kinneloa West, (7) Kinneloa East, (8) Carriage House, (9) Sunnyside, (10) Bailey, (11) Auburn, (12) Carter, (13) Sierra Madre Dam, (14) Lannan.

Study Area and Methodology

Figure 1 presents a map of the surveyed debris basin locations relative to the wildfire-affected region.

Data Collection

To conduct high-resolution surveys of debris basins, we utilized the following equipment:

- **Unpiloted Aerial Vehicle:** DJI Matrice 350 RTK, a high-precision drone with real-time kinematic (RTK) capabilities for accurate georeferencing.
- **Lidar Sensor:** DJI Zenmuse L2, a high-resolution lidar system optimized for topographic mapping and terrain modeling. With its five-return capability, this lidar sensor enables effective vegetation filtering.
- **RTK GPS Base:** Emlid Reach RS3, a multi-band GNSS receiver used for the RTK GPS correction.
- **Power System:** DJI BS65 Intelligent Battery Station with five pairs of DJI TB65 batteries, ensuring extended flight operations. A portable power generator is also used to recharge batteries in the field, allowing for continuous operation by alternating battery usage efficiently.
- **Software:** DJI Terra, used for lidar data processing, point cloud generation, and bare ground classification.

We conducted UAV surveys at an altitude of 100–120 meters above ground level, utilizing the terrain-following feature to maintain a consistent ground sampling resolution. This approach resulted in a 3.5 cm / pixel resolution and a point density of 500-700 points / m^2. We set an 80% front overlap and a 20% lateral overlap between data frames. Additionally, RGB image collection during surveys was enabled to colorize the point clouds. The UAV operated at a maximum speed of 15 m/s, with an average flight speed of 6 m/s.

We collected UAV LiDAR data from debris basins affected by the Eaton wildfire to assess post-fire sediment accumulation and remaining basin capacity. Table 1 provides an overview of the surveys conducted, including flight dates and locations. Figure 2 illustrates point clouds from the UAV lidar surveys and data processing, and full results for each basin are given in Appendix Table A1. The lidar dataset of the basins has been publicly archived and is accessible at https://doi.org/10.5281/zenodo.14948376.

Debris Basin	UTM Easting	UTM Northing	01/25	02/10	02/14	02/19	02/23
Auburn	402628	3781985	X	X	X	X	X
Bailey	402170	3781770	X	X	X	X	X
Carriage House	401459	3782180		X	X	X	X
Carter	403230	3781969	X	X	X	X	X
Eaton Wash	391724	3783525					X
Devonwood	395770	3785730				X	X
Gooseberry	396794	3784182				X	X
Kinneloa East	400139	3782993					X
Kinneloa West	399959	3783044					X
Lannan	404809	3781773					X
LasFlores	396182	3785103				X	X
Sierra Madre Dam	403899	3782179				X	X
Sunnyside	401777	3782085		X	X	X	X

Table 1: Debris Basin Flights Following the 2025 Eaton Wildfire

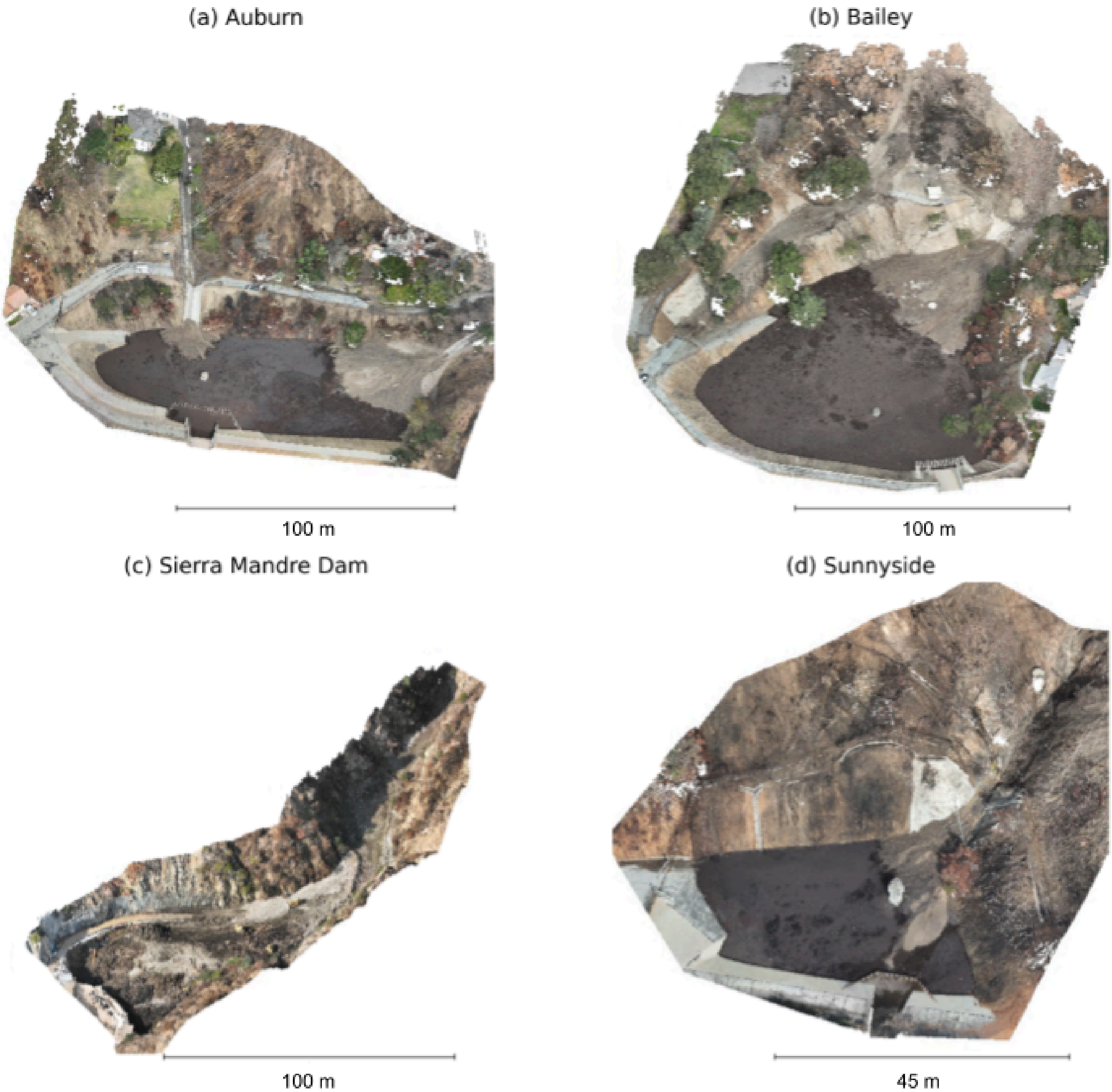

Figure 2: Example point clouds from UAV lidar surveys: Auburn, Bailey, Sierra Madre Dam, and Sunnyside.

Classification of Bare Ground

We used DJI Terra post-processing software to classify the ground points in the lidar data. Figure 3 presents the bare ground classification derived from multi-return lidar data, highlighting how vegetation and other obstructions were filtered out. We generated a DSM by projecting point clouds onto the horizontal plane and derived a DEM by filling non-data pixels using linear interpolation. Figure 4 illustrates the resulting digital elevation model (DEM; bare ground) and digital surface model (DSM; highest lidar return) for the Bailey debris basin.

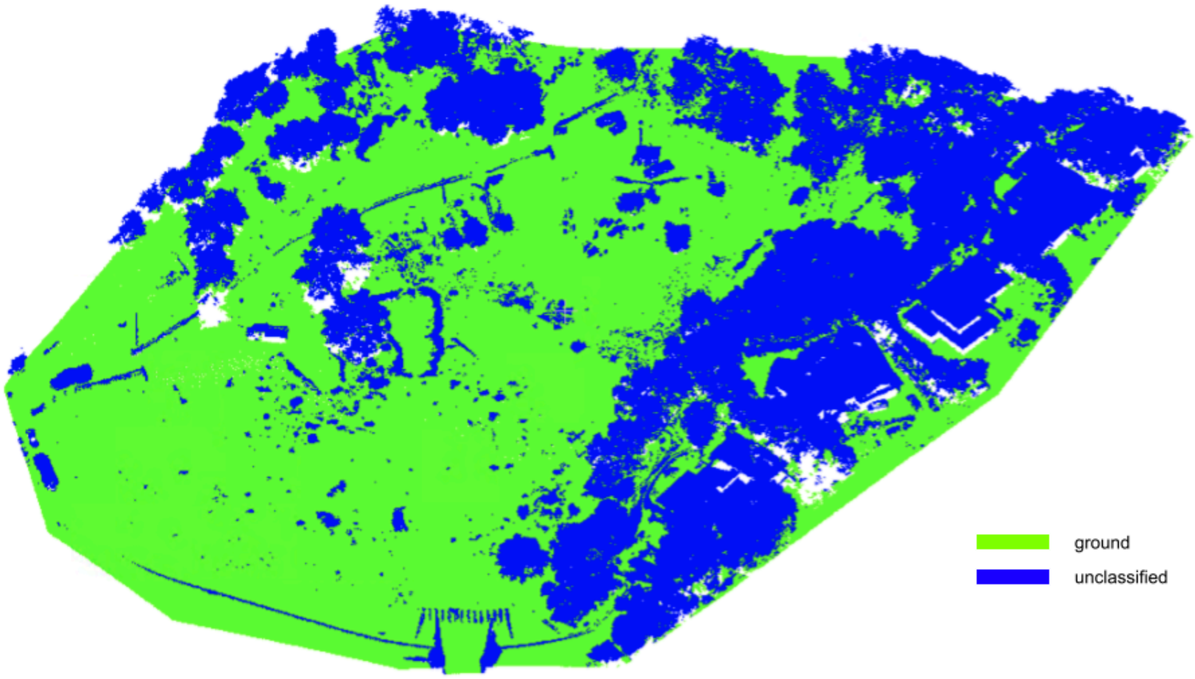

Figure 3: Point cloud ground classification for the Bailey debris basin surveyed on Feb 23rd, 2025.

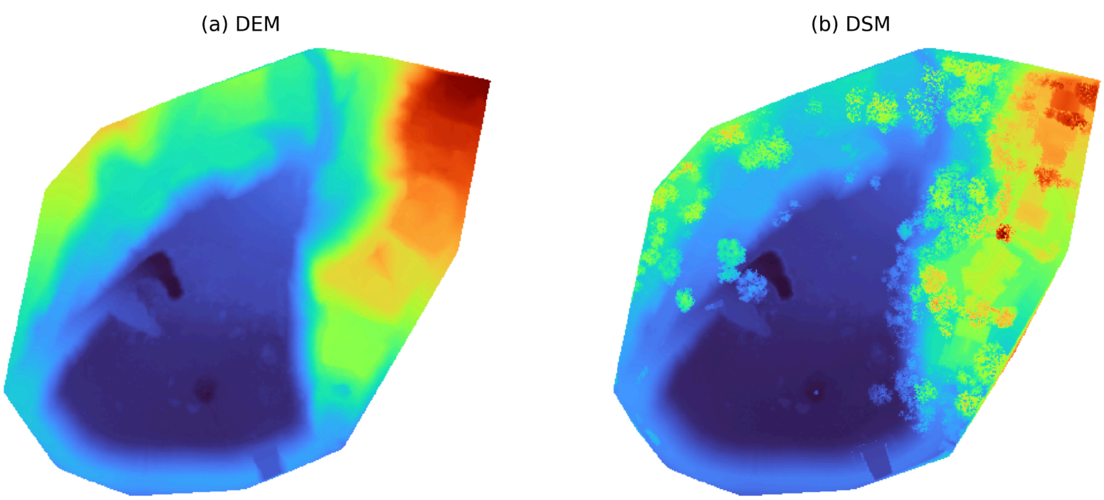

Figure 4: Digital Elevation Models (DEM) and Digital Surface Models (DSM) for the Bailey debris basin surveyed on Feb 23rd, 2025, showing the effect of filtering the vegetation.

Estimation of Debris Volumes

We calculated the debris volumes delivered to the basins marked in Fig. 1 by differencing the ground-classified point clouds from our post-storm UAV lidar surveys to the pre-storm airborne lidar data (DEMs) collected on January 20, 2025 (NV5 and University of California-San Diego, 2025).

In anticipation of the post-fire rainfall and associated debris flows, LA County Public Works (LACPW) excavated material from six of the studied debris basins (Auburn, Devonwood, Kinneloa East, Lannan, Rubio, and Sierra Madre Dam) in the time interval between the pre-storm and post-storm lidar surveys (January 20, 2025 to February 13, 2025) (Dai Bui, personal communication). We account for this additional excavated volume in our final estimates of debris volumes (Table 2).

Calculating debris volumes from the pre- and post-storm lidar datasets required accurate 3D co-registration of the two elevation datasets. We co-registered the data using a two-step procedure. First, we performed a (meter-scale) co-registration of the DEMs following the Nuth & Kääb (2011) procedure. Second, we fine-tuned the co-registration (cm-scale) by iteratively searching small dx, dy, dz co-registration offsets in an optimization procedure to minimize the mean absolute elevation change in the region outside the debris basin (NV5 and University of California-San Diego, 2025). Figures S1-S2 in the Appendix illustrate the elevation changes in the pre-storm to post-storm datasets both before and after co-registration. We used the co-registered datasets to calculate the final volume changes.

Results

Table 2 presents the volumes of material delivered to each debris basin during the Feb. 13-15 storm. Figure 5 shows the sedimentation volumes relative to each basin's design capacity. Overall, the debris basin capacities following the storm event were reduced by 12 - 59 % of their design capacities (Los Angeles County Department of Public Works, 2025). Figure 6 shows that the sedimentation volumes decrease slightly over time due to dewatering.

Debris basin	Easting [m]	Northing [m]	Design Capacity (CY)	Vol. change from 2025-01-20 to 2025-02-23 (CY)	Excavated vol. from 2025-01-20 to 2025-02-13 (CY)	Vol. deposited during storm (CY)	% of design capacity filled during storm
Auburn	402628	3781985	37710	13566	1010	14576	39
Bailey	402170	3781770	128777	45536	0	45536	35
Carriage House	401459	3782180	13300	2064	0	2064	16
Carter	403230	3781969	27700	4940	0	4940	18
Devonwood	395770	3785730	10900	2323	600	2923	27
Eaton	391724	3783525	1542347	182541	0	182541	12

Gooseberry	396794	3784182	33857	12246	0	12246	36
Kinneloa East	400139	3782993	36000	17689	2185	19874	55
Kinneloa West	399959	3783044	35000	20634	0	20634	59
Lannan	404809	3781773	41400	15269	2280	17549	42
Las Flores	396182	3785103	54800	29510	0	29510	54
Rubio	396529	3784831	148040	34270	12060	46330	31
Sierra Madre D	403899	3782179	136400	73576	3530	77106	57
Sunnyside	401777	3782085	5000	1806	0	1806	36

Table 2: Estimated debris volumes deposited during the Feb. 13-15 2025 storm event.

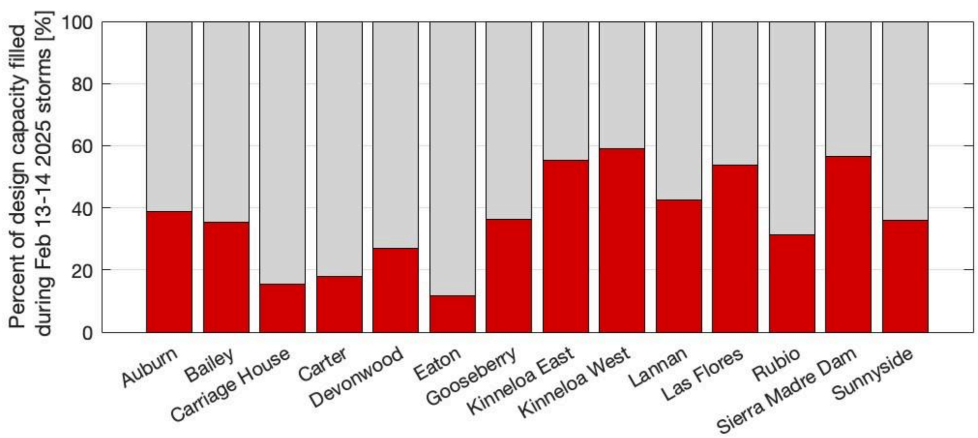

Figure 5: Estimated debris volumes delivered to each basin during the Feb. 13 storm event, plotted as a percent of each basin's total design capacity.

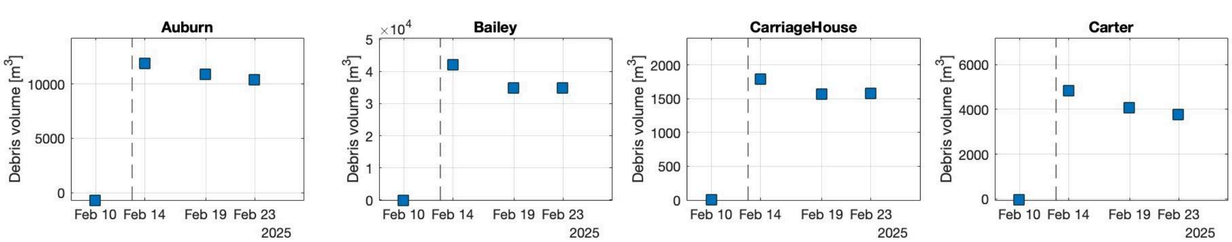

Figure 6: Post-storm volume changes for the four debris basins with at least three post-storm UAV lidar surveys. The gradual reduction in volume reflects the dewatering of the debris basins as the water towers were cleared.

Conclusions

This study demonstrates the effectiveness of UAV-based lidar surveys in rapidly assessing debris volumes and remaining debris basin capacities following the 2025 LA Wildfires. By leveraging high-resolution point clouds, we classified bare ground surfaces and generated DEMs to estimate sediment accumulation. Our results highlight variability in sediment deposition across different debris basins, with some retaining substantial capacity while others have been heavily impacted by post-fire debris flows. Our estimates can be used to prioritize debris basin cleanouts and to inform hazard forecasting and debris flow mitigation strategies before the next storm event.

Data Availability

The lidar data for the basins has been publicly archived and is accessible at https://doi.org/10.5281/zenodo.14948377.

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Nuth, C., & Kääb, A. (2011). Co-registration and bias corrections of satellite elevation data sets for quantifying glacier thickness change. The Cryosphere, 5(1), 271–290.

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Acknowledgements

We thank D. Dalmia, H. Martin, and J. Nghiem for helping with field surveys. Debris basin access was facilitated by D. Bui at LA County Public Works. I. Nasseri provided debris basin capacity estimates. Funding was provided by a generous gift from C. Trimble to Caltech. Z. Chen is supported by Caltech Seismological Lab and USGS. E. Geyman is supported by an NSF Graduate Student Research Fellowship and the Fannie and John Hertz Foundation. We appreciate the funding support from Caltech Center for Autonomous Systems and Technologies (CAST).

Appendix 1

Debris basin	Survey date	Survey time (PST)	Volume change from Jan-20-2025 (m3)	Volume change from Jan-20-2025 (CY)
Auburn	1/25/25	13:16	-327	-428
Auburn	2/10/25	13:14	-686	-897
Auburn	2/14/25	10:26	11860	15512
Auburn	2/19/25	12:08	10899	14255
Auburn	2/23/25	13:13	10372	13566
Bailey	1/25/25	13:16	338	442
Bailey	2/10/25	13:14	-23	-30
Bailey	2/14/25	10:26	42030	54973
Bailey	2/19/25	12:08	34950	45713
Bailey	2/23/25	13:13	34815	45536
CarriageHouse	2/10/25	14:37	10	13
CarriageHouse	2/14/25	9:51	1788	2339
CarriageHouse	2/19/25	12:08	1570	2053
CarriageHouse	2/23/25	13:13	1578	2064
Carter	1/25/25	13:16	-100	-131
Carter	2/10/25	13:14	-51	-67
Carter	2/14/25	10:26	4848	6341
Carter	2/19/25	12:08	4083	5340
Carter	2/23/25	13:13	3777	4940
Devonwood	2/19/25	15:55	1771	2316
Devonwood	2/23/25	16:37	1776	2323
Eaton	2/23/25	15:56	139563	182541
Gooseberry	2/19/25	15:55	9075	11870
Gooseberry	2/23/25	16:37	9363	12246
KinneloaEast	2/23/25	15:41	13524	17689
KinneloaWest	2/23/25	15:41	15776	20634
Lannan	2/23/25	14:49	11674	15269
LasFlores	2/19/25	15:55	22931	29993
LasFlores	2/23/25	16:37	22562	29510
Rubio	2/19/25	15:55	27916	36513
Rubio	2/23/25	16:37	26201	34270
Sierra Madre Dam	2/19/25	14:43	57825	75632
Sierra Madre Dam	2/23/25	14:08	56253	73576
Sunnyside	2/10/15	14:37	-24	-31

Sunnyside	2/14/25	9:51	1561	2042
Sunnyside	2/19/25	12:08	1406	1839
Sunnyside	2/23/25	13:13	1381	1806

Table A1: Volume changes from repeat UAV lidar surveys between 2025-01-25 and 2025-02-23. The volume changes are all measured relative to the pre-storm 2025-01-20 airborne lidar survey from NV5. The unit “CY” denotes cubic yards.

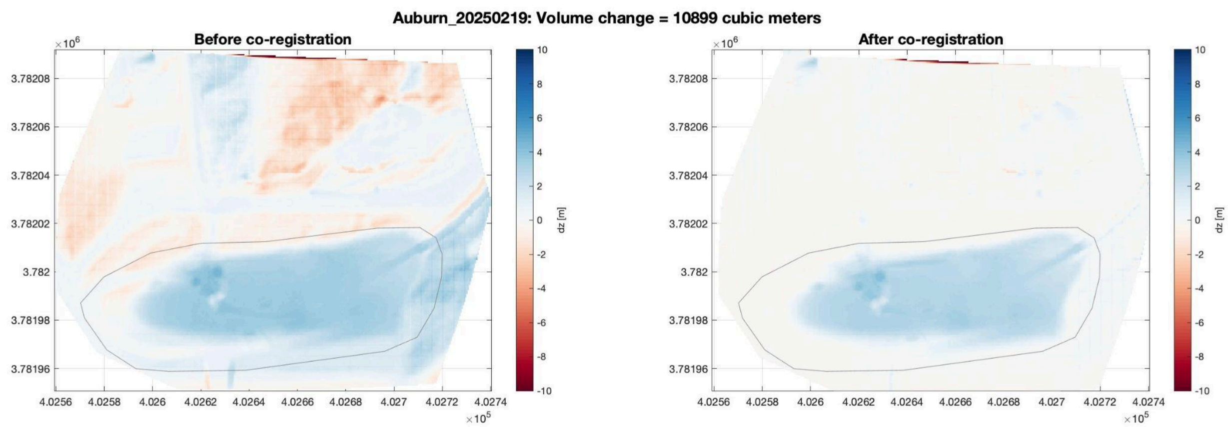

Figure S1: An illustration of the debris basin volume change calculated by differencing the UAV lidar DEM (post-storm survey) to the NV5 airborne lidar DEM (pre-storm survey). This example shows the Auburn debris basin. Before the two datasets are co-registered, elevation difference exists outside the debris basin, which varies systematically with the terrain aspect. This aspect-dependent elevation change is a diagnostic fingerprint of a co-registration offset between the two datasets (Nuth & Kaab, 2011). After co-registering the two datasets, elevation difference outside the debris basin is minimized. We calculate the sedimentation volume by summing the elevation changes within the black polygon outlining the debris basin.

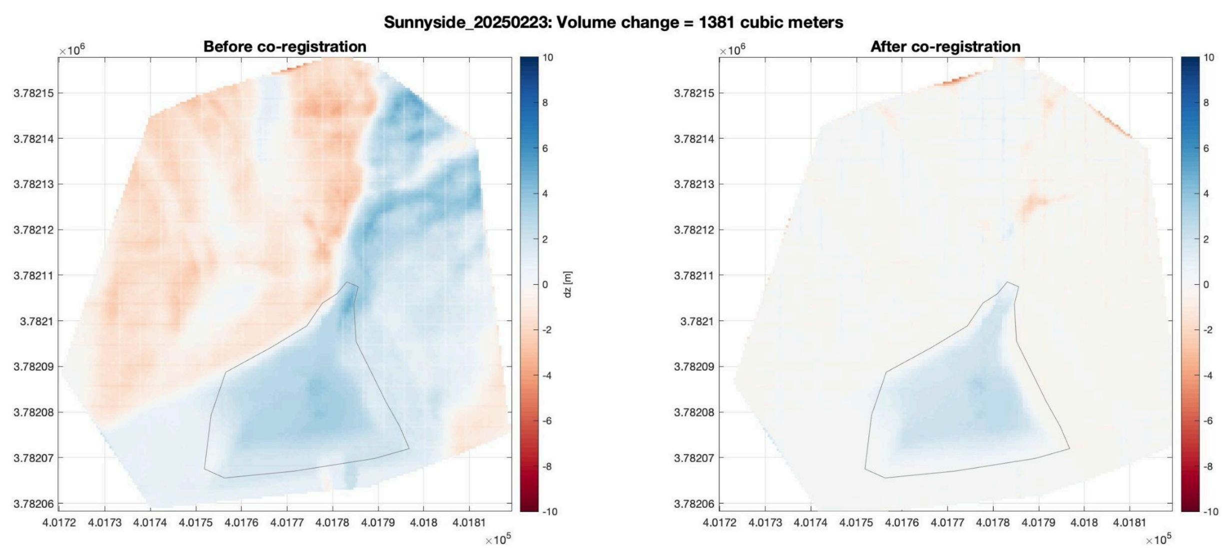

Figure S2: An illustration of the debris basin volume change for the Sunnyside debris basin.