Drone (sUAS) Imagery of Debris Basin Infrastructure Supports Watershed-Scale Assessment and Preparation for Changing Flood and Geologic Hazards in Santa Barbara, California

Marc Mayes[1,2*], Arthur Sylvester[3], Kelly Caylor[1] | *mmayes@ucsb.edu @mrcmayes |

1-Princeton Environmental Institute, Princeton University, Princeton, New Jersey USA
2-Earth Research Institute, University of California-Santa Barbara, Santa Barbara, CA USA
3-Dept. of Earth Science, University of California-Santa Barbara, Santa Barbara, CA USA

Goals:

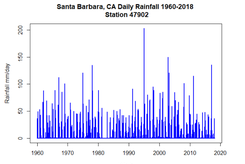
(1) Compare designed and current volumes of flood-control debris basins to USGS sediment yield predictions for post-fire debris flow events, as part of recent disaster recovery and future planning efforts in Santa Barbara County, California.

(2) Develop framework for the use of drones (sUAS – small unmanned aerial systems) to aid flood infrastructure monitoring among local government, emergency management and academic geoscience communities.

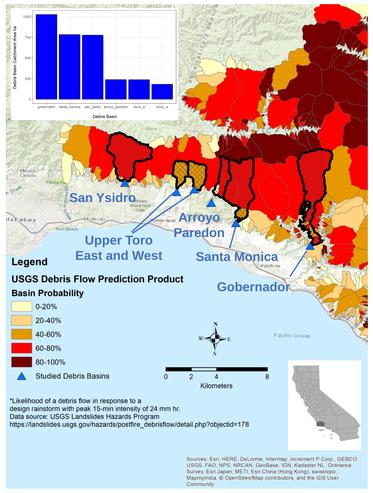
Motivation: Recovery and preparation for future "one-two punches" of severe wildfires and debris flows.

How does 1960s-70s era infrastructure capacity compare with current debris flow hazards across large and small watersheds?

- Severe wildfires, such as the recent Thomas Fire (Dec 2017), leave watersheds denuded and prone to mass wasting events.
- 50-year trends of hotter June-Nov temperatures, and increasingly episodic rainfall, increase likelihood of severe fires and landslide hazards.
- Land-use, flood, and emergency managers need data on flood infrastructure and watershed conditions to mitigate and plan hazard responses.



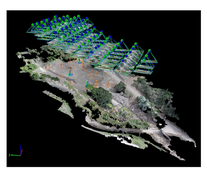
Study area: Six catchments and debris basins affected by Thomas Fire and Jan 9 Debris Flows.



Methods: Measure debris basin volumes across catchments with sUAS image-based 3D models, and compare with past survey, engineering data and USGS sediment-yield predictions.

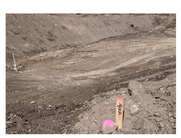
Drone imaging workflow:

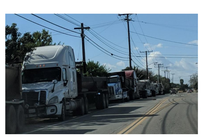
- DJI Phantom 4 and Inspire 1.
- Autonomous grid flights over basin areas.
- Structure-from-Motion point cloud and volume analysis with Pix4D, Cloud Compare.



Integration with County survey and engineering data

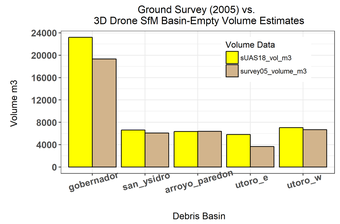
- Worked with SB County Flood Control Surveyor for ground control points.
- Data sharing with county for basin design specifications, and volumes of removed debris.



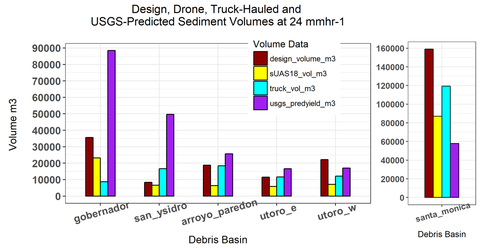


Results: Drone imaging provided rapid, low-cost assessments of debris basin volumes after post-disaster clean-outs.

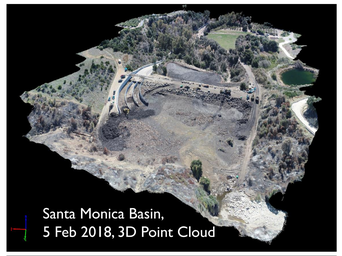
- sUAS basin-empty volume estimates are within ±15% of past ground survey estimates.



- Debris volumes hauled by truck are rough "ground-truth" checks on USGS-predicted sediment yields.

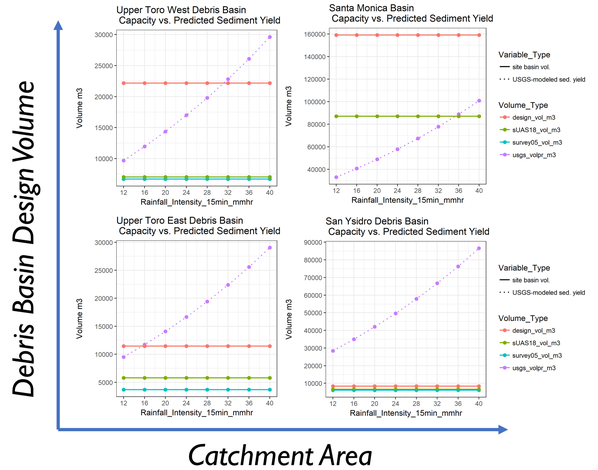


- Removal of 70,000 m^3 material quantified during cleanout of 160,000 m^3 Santa Monica debris basin over two months.



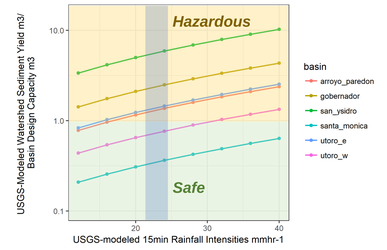
Results: Small- to mid-size basins in smaller catchments are ripe for sUAS surveys to inform debris basin management.

- Where basin design volumes intersect sediment yield curves, sUAS monitoring has biggest potential impact for informing cleanout to prevent over-topping.
- Where design volumes are greater than predicted sediment yields, sUAS can be helpful for clean-out monitoring and structural assessment.
- Volume estimates from 2005 ground survey and 2018 sUAS are similar, but 0.3-3x smaller than design volumes from 1960s-1970s.



Integration: Planning for future flood infrastructure needs based on recent extreme events

- The log-ratio of sediment yield : basin design capacity vs. USGS-sediment yields for design storms, gives a theoretical guide to how current infrastructure relates to mass wasting hazards.
- Blue stripe indicates range of maximum rainfall intensities at 3:45AM PST, Jan 9, 2018, the time of debris flows.



- San Ysidro and Gobernador basins have largest gap, infrastructure capacity relative to sediment yields, for coming years.

Challenges for monitoring:

- Difficult to measure "true" debris flow volumes given overflow, drainage from basins.
- Large uncertainties in the way debris flows "mound" behind spillways; leads to discrepancies between design capacity and "basin-empty" volume estimates.
- Truck-reported volumes are what taxpayers pay to remove in cleanouts, but estimating cost from basin dimensions or "pile" volumes is difficult because material "fluffs", expanding in volume, when broken up and loaded in trucks.
- Maintaining permanent survey markers in the field for repeat monitoring with sUAS over time.

Next steps:

- Codifying MOU between UCSB and S.B. County for further outreach for hazard management.
- Collaboration with others using sUAS for flood and other infrastructure assessment pre- and post-hazard.
- sUAS to inform ecological restoration

Acknowledgments and References

Tom Fayram, Scott Bricham, Jon Frye at SB County Flood Control; Chief Ray Navarro, Carpinteria/Summerland Fire Protection District.; Eric Isaacs, sUAS pilot for 30 March 2018 basin surveys flights; USGS Landslide Hazards Program for landslide hazards model data, Dr. Brandon Stark.
Funding: Nature Conservancy NatureNet Postdoctoral Fellowship to Marc Mayes (2016-2018).