THE PARTNERSHIP
FOR RESILIENT COMMUNITIES

October 22, 2018

By Hand Delivery

Ms. Dianne Black,

Director, Planning & Development Department

County of Santa Barbara

123 E. Anapamu Street

Santa Barbara, CA 93101

Re: Montecito Emergency Debris Flow Mitigation Project.

Dear Director Black:

The January 9, 2018 debris flow was catastrophic – in addition to the loss of 23 lives in the Montecito area, approximately 470 homes and other structures were damaged and/or destroyed.[1] With the 1/9 Debris Flow closing the 101 Freeway, individuals and businesses were disrupted throughout California.

The Partnership for Resilient Communities (TPRC) was formed by county residents shortly after the 1/9 Debris Flow as a 501(c)(3) non-profit community organization focusing on recovery, safety and resiliency efforts, including most critically on debris flows.[2]

TPRC proposes this temporary, removable nets Project as demanding immediate action to prevent or mitigate loss of, or damage to, the lives, health and property of county residents, and essential public services, from the sudden and unexpected occurrence of the clear and imminent danger of debris flows originating in the watersheds decimated by the 281,893-acre Thomas Fire.

Emergency Status.

Chief Kevin Taylor was the Incident Commander for the 1/9 Debris Flow for the combined public safety agencies responding to the disaster. Chief Taylor is also the Operations Chief for the Montecito Fire Protection District, with continuing jurisdiction for public safety over the Montecito area.

Chief Taylor on October 21, 2018 confirmed in written correspondence "*that the Montecito Fire Department and the XSB IMT 3 [the Santa Barbara County Operational Area Incident Management Team] both consider the community of Montecito to be at imminent risk for Debris Flow should we experience short duration, high intensity rainfall. This assessment is based on multiple scientific studies*

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[1] May 15, 2018 Board Letter from Planning & Development Department to Santa Barbara County Board of Supervisors (BOS) re Like-for-Like Debris Flow Rebuild Ordinance.
[2] May 1, 2018 Agenda Letter from County Executive Office to BOS re TPRC.

indicating that a large amount of debris that can be readily mobilized is loaded on the slopes above the community. Given the damage to the watershed from the Thomas Fire, this condition is expected to persist for at least the next 4-5 years."

BGC Engineering Inc., Golden, Colorado, prepared the enclosed analysis dated August 31, 2018. The analysis is authored and executed by four experts, including Dr. Matthias Jakob, the leading global expert in debris-flow risk assessment and the author of the standard textbook on the topic.

Among other findings, the BGC Engineering Inc. analysis states that:

"Urgent action is needed to protect life and property in Montecito from the impacts of future debris flows. The January 2018 debris flows did by no means "remove" the hazard or return the watersheds to "pre-fire" conditions. The likelihood of debris flows this winter remains high because vegetation has only tentatively begun to re-establish following the fire, and the approaching season of rainfall beginning in November could trigger a subsequent round of debris flows from the denuded watersheds above Montecito."

The engineers also conclude that *"winter rains are coming to Montecito soon, via atmospheric river or otherwise, and a period of high debris-flow hazard will come with them. BGC strongly encourages urgent action to protect public safety and property in Montecito from subsequent debris-flow disasters."*

Chief Taylor's public safety opinion, the BGC Engineering Inc. expert analysis, NOAA's publicly available prediction of 70+ chance of an El Niño rain event this winter, and common sense current visual evidence of extensive boulders and debris in the five canyons above Montecito, provide substantial evidence supporting the finding of an emergency pursuant to Pub Res C §21080(b)(4); 14 Cal Code Regs §15269(c); and Pub Res C §21060.3.[3] See also Fish and Wildlife Protection and Conservation section 1601(c).

Project Description:

The Project is a debris flow prevention and mitigation system that will be located in five canyons north of the community of Montecito in Santa Barbara County, California: Cold Spring Canyon, Hot Springs Canyon, San Ysidro Canyon, Buena Vista Canyon and Romero Canyon. The Project involves the installation of 15 Geobrugg flexible debris control nets.

The basic debris flow protection system consists of a steel ring net engineered to resist the velocities and dynamic and static pressures unique to debris flows. Support ropes are installed into channel banks and transfer debris impact and pressure loads from ring nets to the ground. Excessive energy is absorbed by net braking elements in the wire support ropes.

The net design calls for a minimum elevation of three feet above the water surface of the low-flow channel to allow for natural stream processes and wildlife use. This space between the water surface and the bottom of the net will be maintained except during high-flow or debris flow events.

[3] "Emergency" includes such occurrences as **fire, flood**, earthquake, or **other soil or geologic movements**, as well as such occurrences as riot, accident, or sabotage. Pub Res C §21060.3. (Emphasis added.)

At precise locations determined by geotechnical and environmental experts and located by latitude and longitude: two nets would be installed in Cold Spring Canyon, two nets would be installed in Hot Springs Canyon, two in San Ysidro Canyon, and seven in Buena Vista Canyon (which lacks any debris basin). Net numbers proposed in each canyon, property owners, and Assessor Parcel Numbers for those nets currently proposed in the County's jurisdiction are listed below:

Net Location	**Owner**	APN(s)
BV-2, -4, -5, -6, -7, -10, -11	Pollock Peggy L Trust; Pollock Thomas Philip Trust	007-020-009
CS-11, -18	Robinson Mary Kay Living Trust	011-010-027, 011-010- 028
HS-6, -7	Land Trust for Santa Barbara County	011-010-030
SY-7, -18	Wilderness BB LLC	151-180-019, 007-020-003

Two additional nets are proposed in Romero Canyon on US Forest Service land and these are outside the County's jurisdiction.

The nets are pre-fabricated to specification for each location. Net installation will be done by Access Limited Construction (ALC) with oversight from KANE GeoTech, Inc. A biologist will be onsite to conduct wildlife surveys, monitor for permit compliance, and provide oversight of construction and maintenance work.

ALC has prepared a Work Plan (ALC 2018) that details the method of installation at each of the 15 net locations. The Work Plan describes access, staging, equipment, and materials to be used at each net location. The method entails general procedures that are adapted to the specific characteristics unique to each site.

In general, equipment and materials will be deployed by helicopter. An Emergency Action Plan (EAP) describes how and under what circumstances work will be curtailed in the event of inclement weather. The EAP explains how weather data will be monitored and analyzed and what thresholds will be used to trigger evacuation protocol.

Maintenance of the debris nets may be necessary if damaged and in need of repair. Annual and post-event inspections will be conducted by the geotechnical engineers and ALC. Minor maintenance can typically be done using tools and materials transported by hand and foot. The need for removal of accumulated debris will depend on frequency, intensity, and the amount of precipitation experienced in the surrounding watershed.

Intense and localized rainfall events as occurred on January 9, 2018 have potential to mobilize soil and debris. The debris retention system will be monitored as described by ALC. Should the nets accumulate sufficient material to block the channel, equipment will be mobilized to the location via aerial transport once streamflow has subsided sufficiently to allow safe access.

When the watersheds are revegetated to pre-Thomas Fire levels, estimated in approximately five years depending on natural drought and vegetation re-growth cycles, the net systems will be removed entirely, generally by helicopter, under the supervision of biologists.

Performance Security to Guarantee Maintenance, Net Removal and Debris Management.

Given the loss of life and over $2 billion in assessed property values – and the high risk of debris flows this winter as outlined in the BGC Engineering Inc. analysis –the Santa Barbara and Montecito communities are supporting and will support all aspects of the Project financially. See, e.g., https://partnershipsb.org/partners/.

TPRC's installation agreement with ALC sets forth -- in addition to mobilization and installation costs -- the expenses of (a) annual maintenance, (b) complete removal in about five years, and (c) interim debris management in the event of a debris flow.

As a condition of TPRC pulling its permit, it will post the County's standard "Corporate Surety Faithful Performance Bond" – or any other performance or surety instrument required by and satisfactory to the County – to fully guarantee the payment in advance of such annual maintenance, removal and debris management costs.

Intent to File Subsequent Application in 2019 for Additional Nets.

As the mitigation report by KANE GeoTech, Inc. dated October 5, 2018 describes, geotechnical engineers identified 71 net sites in the above five canyons that have the potential to catch significant quantities of debris above Montecito during the next five years. Of these 71 sites, 15 were chosen for this emergency permit. TPRC intends to file a subsequent application in 2019 for an approximately 25-35 additional nets.

TPRC Commitment to Additional Monitoring, Warning, and Long-Term Regional Resiliency Measures.

In addition to temporary, removable nets, TPRC on behalf of the community continues to research, assess, design, permit and implement additional emergency and long-term resiliency measures in accordance with its mission. TPRC's mission is summarized in the May 1, 2018 Board Letter from the County Executive Office to the County Board of Supervisors, including the following four goals:

"A. To determine feasible mitigation efforts to reduce the risk of future debris flows of the magnitude that Santa Barbara County residents have experienced;

B. To engage national and global level experts experienced in disaster mitigation and recovery to work in concert with Santa Barbara County, special districts, school districts, and federal and state agencies and citizens, to rebuild communities that are safer than before;

C. To assist local governments in attracting and receiving incremental public funding and private sector resources; and

D. To provide our lessons learned and solutions discovered to other communities in the future that may suffer similar disasters."

As Appendix C to the KANE report describes in detail, TPRC is working with experts and universities across the nation in respect to:

- Developing advanced monitoring and warning cameras;
- Developing an advanced system of rain gauges placed at various elevations that include video camera, radar sensors, geophones, piezometers and soil moisture instruments.

- In conjunction with the UCSB's Bren School, investigate natural vegetation irrigation via watering most at risk areas; and

- Respond and share information statewide as wildfires result increasingly in massive burn scars that lead to the potential for further deadly debris flows.

Thank you for your time and attention to this critical project for our public safety.

THE PARTNERSHIP FOR RESILIENT COMMUNITIES
Pat McElroy
Executive Director

Encl: "Montecito Debris-Flow Risk Management – Urgent Action Needed" analysis by BGC Engineering Inc. dated August 31, 2018

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY
701 12th Street – Suite 211
Golden, CO USA 80401
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August 31, 2018
Project No.: 1890-001

Suzanne Elledge
Planning & Permitting Services, Inc.
1625 State Street, Suite 1
Santa Barbara, CA 93101

Dear Suzanne,

Re: Montecito Debris-Flow Risk Management – Urgent Action Needed

The Partnership for Resilient Communities (TPRC) retained BGC Engineering Inc. (BGC) to support their debris-flow risk management efforts. TPRC requested that BGC submit this letter to you in support of urgent mitigative action to manage debris-flow risk faced by residents of Montecito. Debris flows in Montecito have occurred repeatedly in the past and will without doubt occur again. The series of high-magnitude debris flows on January 9, 2018 demonstrated that mud, large boulders, and up-rooted trees from the burned area can race into populated areas with very little warning and cause loss of life and devastation to property and infrastructure.

Urgent action is needed to protect life and property in Montecito from the impacts of future debris flows. The January 2018 debris flows did by no means "remove" the hazard or return the watersheds to "pre-fire" conditions. The likelihood of debris flows this winter remains high because vegetation has only tentatively begun to re-establish following the fire, and the approaching season of rainfall beginning in November could trigger a subsequent round of debris flows from the denuded watersheds above Montecito.

The following points demonstrate the reality of debris-flow threat and urgency to prepare:

1. The community of Montecito is located on geologic landforms called alluvial fans (or debris-flow fans) which were created by debris flows and debris floods of the past (Minor et al. 2009). The fans of the individual creeks merge and overlap between the mountain front and the ocean where Montecito is located. Debris flows in the Santa Ynez mountains above Montecito have occurred repeatedly in the past (Minor et al. 2009; Kean et al., 2011, Gartner et al., 2014) both before and after development, and will without doubt occur again.
2. The increased threat of debris flows following wildfire has been recognized in southern California since the early 1900's (Eaton et al., 1935) and have periodically caused extensive damage and fatalities including: extensive damage in Glendora, CA in 1969 (Scott et al., 1971), 16 fatalities on Christmas Day 2003 in San Bernardino, CA (Los

Angeles Times, 2003) and extensive damage following the 2009 Station Fire near La Canada-Flintridge, CA (USGS 2018).

3. As demonstrated on January 9, 2018, debris flows at Montecito can be highly destructive, and greatly exceeded the impacts predicted by FEMA[1]'s map of clear-water flood hazards (FEMA 2018). Debris flows travel at higher speeds, carry up-rooted trees and large boulders (car-sized or greater), and greatly exceed the capacity of Montecito's existing sediment basins and channels.
4. An abundant supply of fine-grained sediment, boulders, tree-trunks, and branches remains in the watershed to be entrained in future flows (Appendix A). The January 2018 debris flows did not exhaust the supply of sediment and large woody debris.
5. The debris flows in January 2018 do not preclude repeat events from occurring in the same watersheds, triggered by subsequent storms. Technical literature documents several examples of multiple debris flows occurring in the same watershed in the years after a fire (Booker 1998; Cleveland 1973; Kean et al. 2011; Scott 1971; Slosson et al. 1989). For example, up to 13 debris-flow events were recorded in basins burned by the nearby Station Fire which burned in the San Gabriel Mountains in 2009 (Staley et al., 2013).
6. Debris flows in California are most likely to occur within the first several winter seasons following a fire (e.g., Cannon et al. 2008). Therefore, debris-flow hazard at Montecito is currently still near its peak level, and the likelihood of a debris flow is still elevated compared to preceding winters when the watersheds were fully vegetated. Recovery of watershed vegetation will diminish debris-flow hazard with time, but will not eliminate it.
7. Occurrence and magnitude of near-future (i.e., next 1 to 5 years) debris flows will be controlled primarily by the intensity of rainfall runoff. The likelihood of a debris flow during the approaching winter is directly related to the likelihood of a heavy or intense rainstorm.
8. The rainfall measured on January 9, 2018 at Montecito was rare (NOAA 2018a), but was not unprecedented in southern California (Cannon et al. 2011). Rainfall intensity was comparable to others that have triggered post-wildfire debris flows in southern California (Cannon et al. 2011). Furthermore, debris flows from burned areas are commonly initiated from rainfall conditions with recurrence intervals of less than five years (Cannon et al. 2008). Figure 1 compares January 9, 2018 rainfall reported by NOAA (2018a) with rainfall events that triggered debris flows in southern California between 1928 and 2010. It also shows that a 1-year return period storm correlates with Magnitude II or Magnitude III debris-flows, which are capable of damaging or destroying infrastructure.

[1] U.S. government, Federal Emergency Management Agency (FEMA)

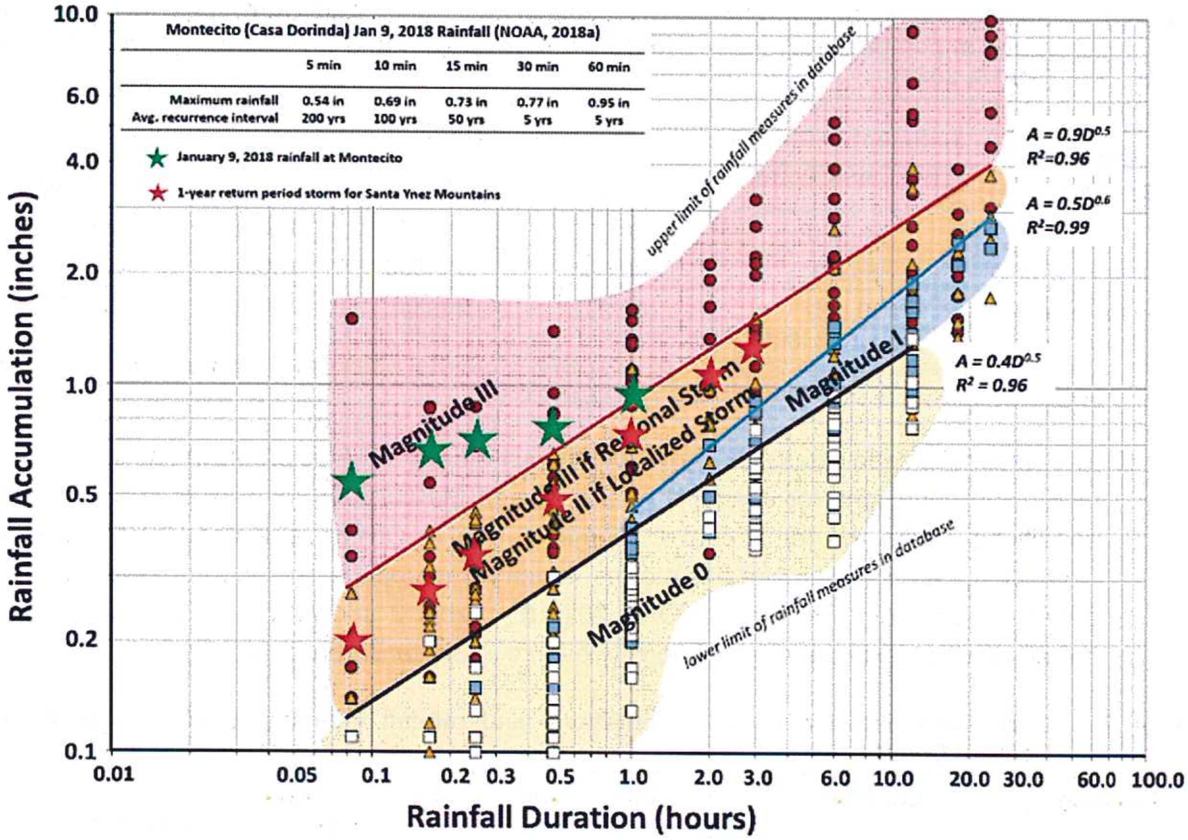

Figure 1. Adapted from Fig. 3 of Cannon et al. 2011. Within-storm rainfall accumulations for storms that triggered debris flows and floods. Open squares are storms with negligible response; blue squares are magnitude I events (small flows, houses damaged, but few large buildings threatened); orange triangles are magnitude II events (moderate flows, damage to houses and infrastructure); red circles are magnitude III events (large flows, buildings and infrastructure may be destroyed); green stars are rainfall reported at Montecito on January 9, 2018 by NOAA (2018a); red stars are rainfall for a 1-year return period in the Santa Ynez Mountains above Montecito (NOAA 2018b)

9. Sediment retention structures in Montecito are not large enough to retain potential post-wildfire debris-flow volumes estimated using U.S. Geological Survey methods (USGS, 2017). Table 1 compares the sediment retention basin capacities to volumes predicted by the USGS debris-flow volume models.

Table 1. Summary of sediment retention basin capacities (Santa Barbara County, 2017) and the range of potential sediment yield from debris flows within the first two years of the fire (USGS, 2017).

Sediment Retention Basin Name	Sediment Retention Basin Capacity (m^3)[1]	Estimated Post-wildfire Debris-Flow Volume (m^3)[2]			
		1-yr	5-yr	10-yr	100-yr
Cold Springs	15,300	90,000	130,000	170,000	330,000
San Ysidro	8,400	80,000	120,000	150,000	290,000
Romero	20,600	60,000	80,000	100,000	200,000

1. Debris basin capacities are from SBC (2017)
2. Volumes estimated using models in the scientific background presented in USGS (2017) based on rainfall intensities at various return periods for Montecito watersheds from NOAA (2018b).

10. The National Oceanic and Atmospheric Administration (NOAA) is predicting a 70% chance of El Niño conditions for January, February, and March 2019 (NOAA 2018c). El Niño conditions cause the jet stream to come ashore in California instead of the Pacific Northwest, carrying moisture and storms, which increases the likelihood of severe rainfall events in Southern California (NOAA 2018d). Table 2 shows that El Niño conditions correlate with maximum rainfall intensity events in Santa Barbara County.

Table 2. Correlation between El Niño conditions and rainfall intensity maximums in Santa Barbara County.

Duration	Location	Water Year	Maximum Rain[1] (inches)	El Niño Conditions[2]?
5 min	UCSB	1998	0.72	Yes
10 min	San Marcos Pass	2015	1.09	Yes
15 min	San Marcos Pass	2015	1.39	Yes
30 min	Stanwood Fire Station	1984	1.80	No
1 hr	San Marcos Pass	1998	2.51	Yes
2 hr	Doulton Tunnel	1973	4.5	Yes
6 hr	Jameson Reservoir	1969	8.78	Yes

Notes:
1. Maximum rainfall recorded in Santa Barbara County from County of Santa Barbara (2018)
2. El Niño conditions based on the Oceanic Niño Index, NOAA (2018e)

In summary, winter rains are coming to Montecito soon, via atmospheric river or otherwise, and a period of high debris-flow hazard will come with them. BGC strongly encourages urgent action to protect public safety and property in Montecito from subsequent debris-flow disasters. Short-term mitigative actions could include upgrades to the early-warning and evacuation protocol, and installation of physical protection such as debris-flow nets. BGC is available to support these efforts, as needed by TPRC and their partners.

CLOSURE

BGC Engineering Inc. (BGC) prepared this document for the account of The Partnership for Resilient Communities. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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Yours sincerely,

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per:

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ABS/MJ/mjp

Attachment(s): Appendix A: BGC Montecito Debris-Flow Risk - Site Reconnaissance Summary

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Appendix A
BGC: Montecito Debris-Flow Risk – Site Reconnaissance Summary

THE PARTNERSHIP FOR RESILIENT COMMUNITIES

Montecito Debris-Flow Risk

BGC Site Reconnaissance Summary

What happened?

A series of debris flows impacted the community of Montecito, Santa Barbara County, California on January 9, 2018, **resulting in 23 fatalities, damage to more than 400 homes, and extensive economic loss**. The Partnership for Resilient Communities (TPRC) invited BGC to complete a reconnaissance-level site visit to Montecito and adjacent watersheds from July 25 to July 27, 2018.

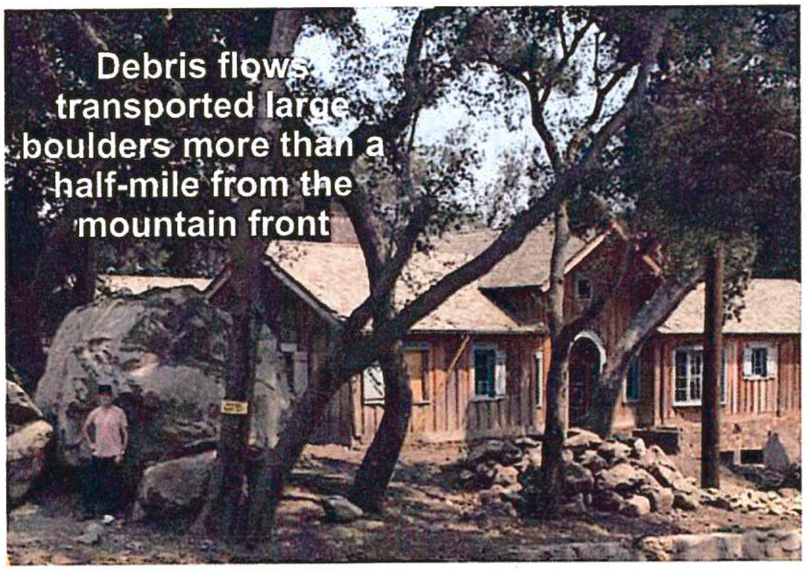
Who is BGC?

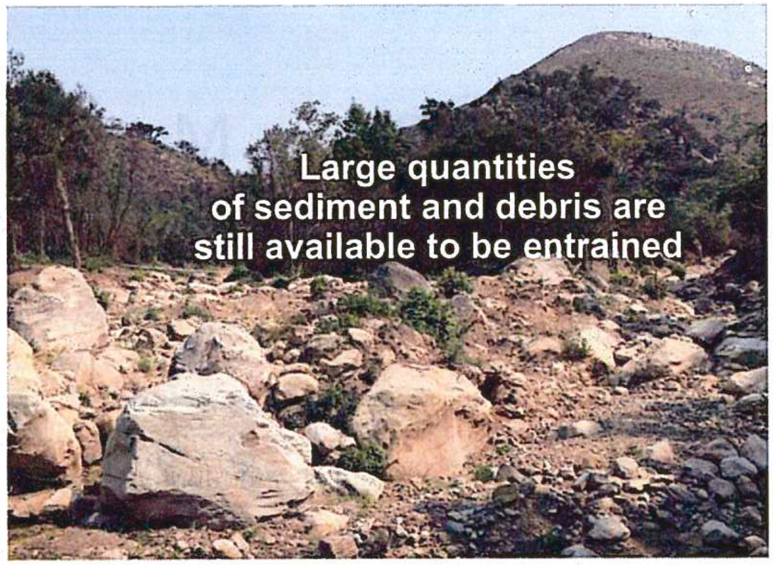
BGC Engineering Inc. (BGC) is a consulting firm providing specialist services in applied earth sciences since 1990, with specific expertise in geohazard risk management. BGC has completed hundreds of debris-flow assessments at individual creeks as well as several regional debris-flow and debris-flood risk prioritization studies. BGC staff have authored key publications on the subject of debris flows.

Field Observations

- The January 2018 debris flows destroyed homes across the entire length of the alluvial fan, from the mouth of canyons to the ocean.
- Some houses close to the fan apex collapsed and were carried away by the flows. **Rapidly flowing mud, large boulders, and woody debris all contributed to damaging and destroying homes.**
- Flow depths of the January 2018 debris flows at the mouth of some Montecito Watershed canyons ranged between 16 and 20 ft.
- The width affected by each flow was commonly between 300 ft to 1,000 ft, while the previously defined creek channels through the community are typically on the order of 16 ft to 32 ft wide.
- Evidence of previous debris flows has been reported and observed, including an anecdote of a swimming pool that filled with mud near San Ysidro creek several times in the previous decades, and landforms on the upper fan area interpreted to be debris flow levees.
- **Large quantities of fine-grained sediment, boulders, and woody debris are still abundantly available to be entrained in flows.**

A destroyed home on San Ysidro Creek.





Interpretation

- The community of Montecito was built on geologic landforms called 'debris-flow fans' that were created by sediment deposited during repeated historical debris flows and floods. **These landforms and other field evidence indicate that debris flows have occurred in the past, and debris flows will occur in the future.**
- The existing sediment basins and channels in Montecito are designed to manage flows that are substantially less than the January 2018 debris flows.
- The January 2018 debris flows appear to have scoured more than 3 ft of material from the channels near the mouth of the canyons. However, **an abundant supply of sediment and debris remains**, including loose sediment on the watershed slopes, loose sediment concentrated in watershed channels, and erodible sediment exposed in channel banks.
- Occurrence and magnitude of near-future (i.e., next 1 to 5 years) debris flows will be controlled more by the intensity of rainfall runoff rather than the abundant availability of sediment. Intensity of runoff is controlled by rainfall intensity, and vegetation cover (which intercepts rainfall and slows runoff). Vegetation cover is currently substantially less than the pre-fire condition.
- **Recovery of vegetation** on watershed slopes will eventually reduce debris flow hazard over time, but vegetation **will not eliminate debris flow hazard.**

Risk Management

- **Implementation of risk management measures is urgent**, as the rainy season begins in November, and NOAA predicts a 70% chance of El Niño in Winter 2019, which increases likelihood of severe rainfall in California.
- The currently proposed debris flow nets should help reduce, but will not eliminate, the debris flow hazard. Additional risk management strategies need to be developed in parallel with the debris flow net design to reduce debris-flow risk to levels deemed tolerable by TPRC, local regulators, and the community of Montecito.
- Debris-flow risk management measures include development of a system for early warning and evacuation, and installation of debris flow nets in the short-term, followed by improvements to physical protection that could include upgrades to debris basins and installation of check dams and conveyance channels.

The January 2018 debris flows were exceptional in historical times in terms of their degree of destruction; however, this does not preclude similar-sized or larger debris flows from occurring in the future. In the absence of adequate risk management, **the consequence of future debris flows could meet or exceed the exceptional consequences of the January 2018 debris flows.**

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August 29, 2018
Project No.: 1890-001

Les Firestein
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Dear Les,

Re: Montecito Debris-Flow Risk – Site Reconnaissance Summary

1.0 INTRODUCTION

A series of debris flows impacted the community of Montecito, Santa Barbara County, California on January 9, 2018, resulting in 23 fatalities, damage to more than 400 homes, and extensive economic loss. The debris flows were caused by high intensity rainfall on Santa Ynez mountain watersheds that had experienced a wildfire (Thomas Fire) during the preceding weeks. After the debris flows, Montecito community members formed a nonprofit organization called The Partnership for Resilient Communities (TPRC) to support disaster recovery and longer-term debris-flow risk reduction.

TPRC invited BGC Engineering Inc. (BGC) to complete a reconnaissance-level site visit to Montecito and adjacent watersheds from July 25 to July 27, 2018. The purpose of the site visit was to observe the state (e.g. burn areas, surficial geology) of the watersheds that generated the January 2018 debris flows and the developed areas of Montecito that were impacted. These observations will inform development of a proposed scope of work that BGC is preparing for TPRC that includes debris-flow hazard assessment, debris-flow risk assessment, and debris-flow risk management.

This letter summarizes BGC's site reconnaissance observations, preliminary interpretations, and recommended short-term actions for debris-flow risk management. It also describes the qualifications and experience of BGC's debris-flow risk management team. This letter is intended to be used by TPRC to inform development of risk management plans for the winter 2018/2019 rainy season. This letter was requested in an email from Les Firestein dated July 30, 2018, and prepared under terms of contract between BGC and TPRC dated August 1, 2018.

2.0 SCOPE OF WORK

BGC's work to date has involved the following components:

1. Approximately 4 hours of review of reports and background information related to the January debris flows that is available on the internet.

2. Reconnaissance-level site visit (July 25-27, 2018) by one BGC representative, Alex Strouth, including:
    a. Meetings with Les Firestein of TPRC.
    b. Meetings with KANE GeoTech Inc. (KANE), who have been retained by TPRC to design debris flow nets to be installed in the canyons upstream of Montecito development.
    c. Meeting with Kerry Kellogg, wildfire specialist at the Montecito Fire Department.
    d. Observation of developed areas of Montecito that were impacted by the January 9, 2018 debris flows.
    e. Observation of the lower portion of Cold Spring, San Ysidro, Buena Vista, and Romero canyons from the start of development to approximately 500 m (1/3 mile) upstream
    f. Observation of the burned watersheds above Montecito from the Camino Cielo Road, located near the ridge line at the top of the watersheds.

3.0 OBSERVATIONS

The following points summarize BGC's observations. Figures that support these observations are attached to this letter.

1. Debris flows that impacted Montecito occurred in the following creeks[1] (from west to east; Figure 1):
    a. Cold Spring Creek and Hot Spring Creek (which join to form Montecito Creek)
    b. Oak Creek (which is a smaller watershed, causing less damage than other creeks)
    c. San Ysidro Creek
    d. Buena Vista Creek
    e. Romero Creek
2. Chaparral shrubland plants densely cover watersheds adjacent to these creeks that were not burned by the Thomas Fire; the slope surface is generally not visible through the Chaparral from a distance except where vegetation has been removed for development or fire break lines (Figure 2). Google Earth imagery suggests that the watersheds that produced the January 9 debris flows had a similar Chaparral cover prior to the Thomas Fire.
3. The Thomas Fire burned most vegetation in the Montecito Watersheds (Figure 3), although the burn severity appears to be somewhat less in Romero watershed compared to the other Montecito Watersheds (Figure 4, Figure 5). The Montecito fire department (K. Kellogg, pers. comm.) reports that the watersheds burned between December 13 and 16, 2017.

[1] Collectively, the watersheds that feed these creeks are referred to as the 'Montecito Watersheds' in this report.

4. Large quantities of fine-grained sediment, boulders, and woody debris are still available to be entrained in flows. This material is located on the watershed slopes, within creek channels in the canyons, and in the scoured banks of the January 2018 debris flow channel (Figure 6, Figure 7).

5. Flow depths of the January 2018 debris flows at the mouth of the Montecito Watershed canyons (as indicated by mud lines on trees and channel banks) typically ranged between 5 m and 6 m (16 ft and 20 ft)[2]. The width of the flow areas typically ranged between 20 m and 50 m (70 ft to 160 ft) within the canyons, near the canyon mouth. A superelevation[3] angle of 8° was measured at a channel bend (50 m radius of curvature, 40 m flow width) in Cold Spring Canyon, approximately 300 m (1000 ft) upstream from the development interface (Figure 8).

6. The January 2018 debris flows destroyed homes across the entire length of the alluvial fan, from the mouth of canyons to the ocean (a distance of 3 km to 4 km (1.9 to 2.5 miles), with a 5% average gradient). Some houses within approximately 1 km to 2 km (0.6 to 1.2 miles) from the fan apex collapsed entirely and were carried away by the flows. The width affected by each flow was commonly between 100 m and 300 m (300 ft to 1000 ft), while the defined creek channels through the community are typically on the order of 5 m to 10 m (16 ft to 32 ft) wide. Rapidly flowing mud, large boulders, and woody debris all contributed to damaging and destroying homes (Figure 9, Figure 10, Figure 11).

7. Evidence of previous debris flows has been reported and observed, including an anecdote of a swimming pool that filled with mud near San Ysidro creek several times in the previous decades, and landforms on the upper fan area interpreted to be debris flow levees (Figure 12).

4.0 INTERPRETATIONS

The following interpretations are based on BGC's observations:

1. The community of Montecito is located on geologic landforms called 'debris flow fans' that were created by sediment deposited during debris flows and floods. The fans of the individual creeks coalesce and overlap on the piedmont between the mountain side and the ocean. These landforms and evidence of boulder levees on the fan indicate that debris flows have occurred episodically in the past (both before and after development of Montecito), and debris flows will occur in the future.

2. The existing sediment basins and channels in Montecito are designed to manage flows that are substantially less than the January 2018 debris flows. For example, superelevation of the Cold Spring creek debris flow (Figure 8) suggests it travelled at

[2] BGC recorded observations in metric units. Approximately equivalent imperial dimensions are provided for the benefit of readers not familiar with metric units.
[3] Superelevation means that a high velocity flow at a channel bend has a higher flow surface on the outside of the channel bend than on the inside. This can be used to estimate flow velocity.

approximately 6 m/s to 8 m/s (13 to 18 miles per hour) at the canyon mouth, through an approximately 200 m^2 (2100 ft^2) channel area, yielding a peak discharge that may have approached 1600 m^3/s (57,000 ft^3/s). The San Ysidro creek debris flow appears to be of a similar scale, with relatively smaller debris flows in the other creeks.

3. The January 2018 debris flows appear to have scoured more than 1 m (3 ft) depth in channels near the mouth of the canyons and fan apex areas. However, an abundant supply of sediment remains, including loose sediment on the watershed slopes, loose sediment concentrated in watershed channels, and erodible sediment exposed in channel banks.
4. Occurrence and magnitude of near-future (i.e., next 1 to 5 years) debris flows will be controlled more by the intensity of rainfall runoff rather than the availability of sediment. Intensity of runoff is controlled by rainfall intensity, and vegetation cover (which intercepts rainfall and slows runoff). Vegetation cover is currently substantially less than the pre-fire condition (compare Figure 2 and Figure 3), but is expected to re-grow and contribute to stabilizing the watersheds with time.
5. Recovery of vegetation on watershed slopes will reduce debris flow hazard but will not eliminate debris flow hazard. Vegetation can be pictured as a 'sponge' sitting atop erodible sediment. The 'sponge' is absent in the first years following a fire, so relatively low rainfall intensities can directly impact erodible sediment, leading to a debris flow. The 'sponge' is thick after vegetation has recovered and can absorb substantial rainfall and soil moisture; however, debris flows can still occur when rainfall continues after the 'sponge' becomes saturated. This example illustrates that relatively low-intensity rainfall that is unlikely to trigger a debris flow in a vegetated watershed can trigger debris flows in a recent burn area, and relatively high-intensity rainfall can trigger debris flows in both burned and vegetated watersheds.
6. Debris flow nets proposed by TPRC and KANE are meant to reduce the volume and intensity of debris flows that reach the community of Montecito. The degree of hazard reduction depends on the number, location, and design of the nets, as well as the magnitude of future events, and has not yet been assessed by BGC or others because net design is in-progress.
7. The currently proposed debris flow nets will not eliminate the debris flow hazard. Other risk management strategies need to be developed in parallel with the debris flow net design to reduce debris-flow risk to levels deemed tolerable by TPRC, local regulators, and the community of Montecito.
8. The January 2018 debris flows were exceptional in historical times in terms of their degree of destruction; however, this does not preclude similar-sized or larger debris flows from occurring in the future. In the absence of adequate risk management, the consequence of future debris flows could meet or exceed the exceptional consequences of the January 2018 debris flows.

5.0 RECOMMENDED SHORT-TERM ACTIONS

The peak debris flow hazard period at Montecito is during the rainy season (typically November to March), particularly during the next few winters before watershed vegetation has fully recovered. Implementation of risk management measures is urgent, as the rainy season begins in 3 months. Furthermore, the National Oceanic and Atmospheric Administration (NOAA) is predicting a 70% chance of El Niño conditions for January, February, and March 2019, which suggests a relatively higher likelihood of severe rainfall events in California (NOAA, 2018). The following recommended short-term actions are intended to guide TPRC as they prepare for the upcoming rainy season.

5.1. Early Warning System and Evacuation

1. Develop an early warning and monitoring system and response protocol that includes evacuation. The short time before the rainy season limits the number and scale of physical mitigation measures (e.g. debris flow nets) that can be constructed. The best method to reduce life-loss risk in the absence of physical protection is timely evacuation of people from hazard zones[4].
2. Educate community members about debris flow hazards, monitoring, and evacuation plans, including for example: debris flow causes and triggers; how the monitoring system works; potential for false alarms; where to go during an evacuation; what to do following a debris flow event.
3. Monitoring and evacuation plans should be informed by the following information:
    a. Establish thresholds for rainfall intensity that could trigger debris flows of varying magnitude.
    b. Debris flow hazard maps identifying zones of relatively high and low debris flow hazard.
    c. Evacuation route maps identifying roads with relatively high and low debris flow hazard.
    d. Assessment of the time needed to alert and evacuate residents.
4. Consider the following monitoring phases:
    a. Monitor forecasted rainfall to identify storms capable of triggering debris flows.
    b. Monitor rainfall intensity observed in Doppler radar and at weather stations along the storm's path.
    c. Install instruments in the debris flow channels, for example cameras and load cells on debris flow nets that identify when a debris flow has initiated. Note that this system will provide only a few minutes of warning prior to the debris flow impacting

[4] Evacuation does not prevent economic loss

development, if the debris flow magnitude is significantly greater than the net capacity. This is not enough time to evacuate, but may allow individuals who have not evacuated to react to the approaching hazard, and the system may be a tool for first responders.

5. Develop a communication plan for informing and alerting residents and first responders along with response and evacuation plans.
6. Consider the following response phases:
    a. Warn residents that a storm capable of triggering debris flows is approaching.
    b. Evacuate residents.
    c. Audible and visual alarms (e.g., sirens, flashing lights) when a debris flow is occurring.

5.2. Physical Debris Flow Mitigation Measures

1. Install debris flow nets proposed by KANE. The nets provide physical protection by capturing debris and potentially slowing the initiation and volumetric growth of debris flows, and can be an important component of the monitoring system.
2. Identify other physical protection that can be installed or improved in the short term. This may include things like removing sediment and debris from existing basins and channels and improving the conveyance capacity of channels.

5.3. Long-term Risk Management Plans

1. Begin developing long-term risk management plans. Elements of the plan may include measures to accelerate revegetation of the watershed, and physical protection such as debris flow basins, check dams, and conveyance channels designed for debris flow magnitudes estimated from a detailed assessment of the watershed.

6.0 BGC EXPERIENCE AND QUALIFICATIONS

BGC is a consulting firm providing specialist services in applied earth sciences since 1990, with specific expertise in geohazard risk management. BGC has completed hundreds of debris-flow assessments at individual creeks as well as several regional debris-flow and debris-flood risk prioritization studies. BGC staff have also authored one of the key publications on the subject of debris flows (Jakob and Hungr, 2005: Debris Flows and Related Phenomena). BGC senior staff have also acted as expert witnesses for debris-flow related litigations and are thus well aware of the intricacies of projects with high litigative potential.

The following recent projects are most relevant to Montecito's debris flow setting and TPRC's objectives:

- Town of Canmore, Alberta: Debris-flood hazard assessment, quantitative risk assessment, mitigation design, and assistance with public policy development related to steep creek hazards. This work followed debris floods in 2013 that caused widespread damage to the town. Many of BGC's reports (including quantitative risk assessments) are available on the town's website: https://canmore.ca/projects/mountain-creek-hazard-mitigation/creek-resources
- Seton Portage, British Columbia: Detailed debris flow hazard and risk assessment for four steep creeks that have impacted homes in the past and led to their abandonment. The work is arguably one of the most sophisticated debris flow and debris flood risk assessments conducted in Canada to date.
- District of North Vancouver, British Columbia: BGC completed quantitative flood, debris flood and debris flow risk assessment and conceptual risk reduction designs for 35 steep creeks within the District of North Vancouver (DNV). The lower portion of these creeks flow through areas containing over 20,000 buildings and a network of roads, utilities, and stormwater management infrastructure. BGC developed an interactive web application to manage complex datasets of development characteristics, hazard scenarios, risk assessment results, and mitigation options in a clear, simple format that can be used for community and risk reduction planning.
- British Columbia Ministry of Forests: BGC completed post-wildfire geohazard risk assessments at four recently burned areas of southern British Columbia. The work focused on assessing debris flow risk to homes and infrastructure, and on prioritizing debris flow mitigation locations and strategies.
- Rio Tinto, Holden Mine near Chelan, Washington: BGC provided a quantitative post-fire risk assessment to guide shutdown criteria at various work sites and along a 10-mile long access road, and to evaluate the safety of the lodging facilities. A warning system was developed to guide when to shut down work activities on the mine in response to intense rainfall. BGC installed a telemetered rain gage at the site to assist Rio Tinto staff to implement the warning system.

BGC's team of debris-flow risk management specialists includes approximately 20 members with diverse backgrounds in geomorphology, hydrology, engineering geology, geotechnical engineering, construction, and geomatics. The team is highly experienced with all project phases, including hazard recognition, detailed hazard assessment, numerical modeling, quantitative safety and economic risk assessment, and design and implementation of risk reduction strategies. Our team has extensive geomatics capabilities, including digital terrain analysis based on high-resolution LiDAR imagery, change detection and quantification, and development of web-based interfaces that allow spatial data to be comprehended, queried, communicated, and modified by our clients.

Key members of BGC's proposed Montecito debris flow risk management team include:

- Dr. Matthias Jakob, PGeo, LG (BGC) – Dr. Jakob is a leading expert in debris-flow hazard and risk assessment, and has completed several hundred such assessments around the world. Dr. Jakob is co-author and editor of the book "Debris-flow Hazards and Related Phenomena", which is the standard reference text book for this topic. Dr. Jakob has also co-authored relevant guidelines for British Columbia and Alberta and continues to research various aspects of applied debris flow science.
- Dr. Joseph Gartner, PE (BGC) – Dr. Gartner is an expert in post-fire debris flow assessment. Before joining BGC in 2014, Dr. Gartner spent 12 years at the U.S. Geological Survey, where he developed models for post-fire debris-flow probability and volume, and rainfall intensity-duration thresholds for post-fire debris flow initiation. His work is used by government agencies to guide design of post-fire erosion mitigation, evacuation route planning, and post-fire debris-flow watches and warnings issued by the National Weather Service. Dr. Gartner is a co-author of the "Wildfire-related debris flow from a hazards perspective" chapter in the book "Debris-flow Hazards and Related Phenomena."
- Alex Strouth, MASc, PE, PEng (BGC) - Mr. Strouth is a specialist in debris-flow risk assessment and risk reduction engineering at scales ranging from site-specific to broad regions. He has worked in a wide variety of settings around the world for linear infrastructure, municipal, and major industry developments. His experience includes all project phases from initial hazard assessment to mitigation design and construction.
- Dr. Paul Santi (CSM) – Dr. Santi is a professor in the Department of Geology and Geological Engineering at Colorado School of Mines (CSM). He will act as a technical reviewer of BGC's work. Dr. Santi's research emphasis is on debris flow analysis and mitigation, with a focus on post-wildfire debris flows in Southern California. He has authored more than 20 peer-reviewed articles related to post-wildfire debris flows during the past decade.

7.0 CLOSURE

BGC Engineering Inc. (BGC) prepared this document for the account of The Partnership for Resilient Communities. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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Yours sincerely,

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ABS/MJ/mjp
Attachment(s): Figures

REFERENCES

National Oceanic and Atmospheric Administration (NOAA). 2018. ENSO: Recent Evolution, Current Status and Predictions. Updated prepared by NOAA Climate Prediction Center, dated 30 July 2018. Available from http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf [accessed July 31, 2018].

Santa Barbara Independent (SBI). 2018. Montecito Mudslides Disaster Assessment Map. Available from https://www.google.com/maps/d/viewer?mid=1tSzYm6DZpootH4aS3STEfYIHYPgak2jO&ll=34.444042466028556%2C-119.65280212535856&z=14 [accessed July 31, 2018].

FIGURES

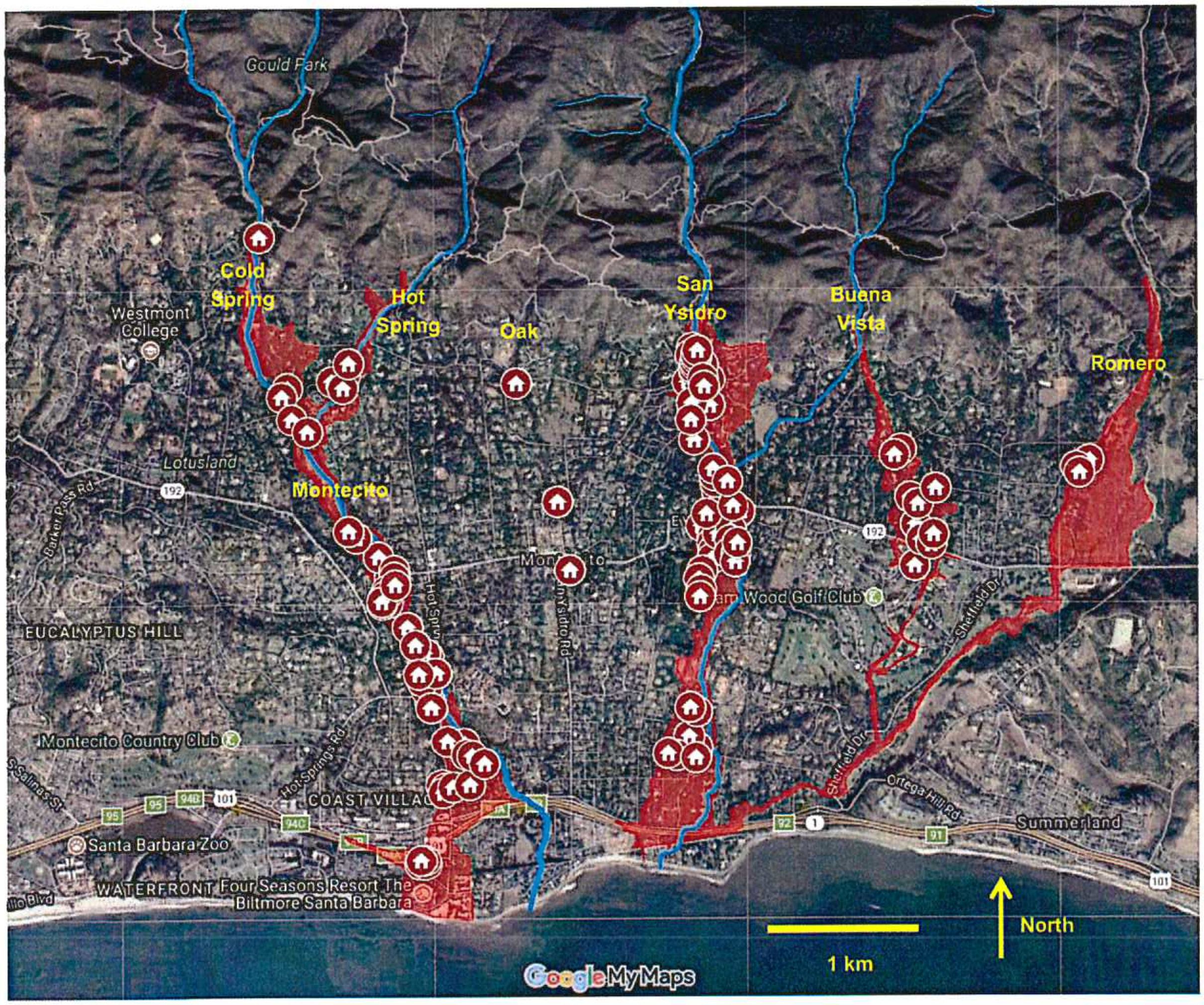

Figure 1. Map of January 9, 2018 debris flows created by the Santa Barbara Independent newspaper (SBI, 2018). Red polygons indicate the debris flow extents, and red symbols indicate homes that 'appear destroyed or majorly damaged'. Yellow labels indicate creek names (by BGC).

Figure 2. Typical chaparral shrubland in a watershed that has not recently burned. This watershed is located immediately north of San Ysidro Creek watershed, adjacent to the Thomas Fire burn area. BGC photo, July 2018, looking north from Camino Cielo Road.

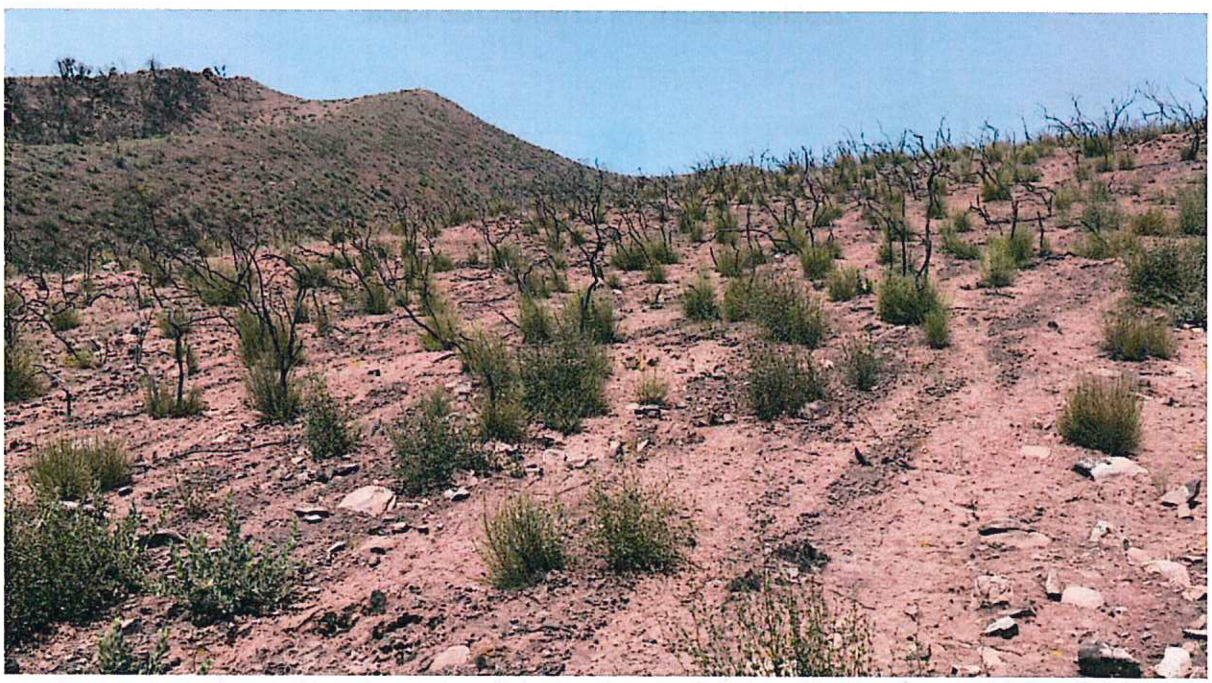

Figure 3. Typical watershed slope following the Thomas Fire. Note lack of vegetation and lack of organic duff layer, and loose soil directly exposed to rainfall. Pioneer vegetation has developed since the Thomas Fire. BGC photo, July 2018, looking northwest from lower Buena Vista Creek watershed.

Figure 4. San Ysidro Creek watershed following the Thomas fire. BGC photo, July 2018, looking south from Camino Cielo Road.

Figure 5. Romero Creek watershed showing a mixture of un-burned and burned areas from the Thomas fire. BGC photo, July 2018, looking south from Camino Cielo Road.

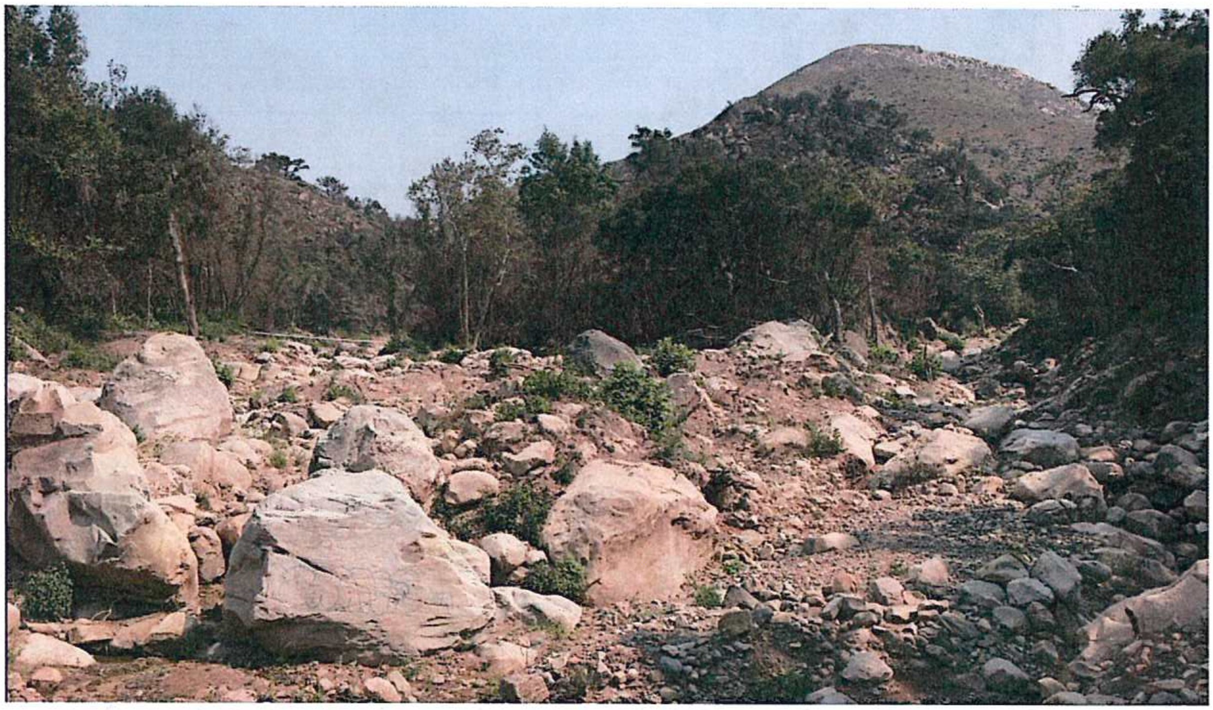

Figure 6. Sediment and boulders in Cold Spring Canyon approximately 400 m upstream from the development interface. Boulders up to 1.5 m diameter in foreground. BGC photo, July 2018, looking north.

Figure 7. Woody debris and erodible channel banks in San Ysidro Canyon approximately 200 m upstream from the development interface. BGC photo, July 2018, looking west.

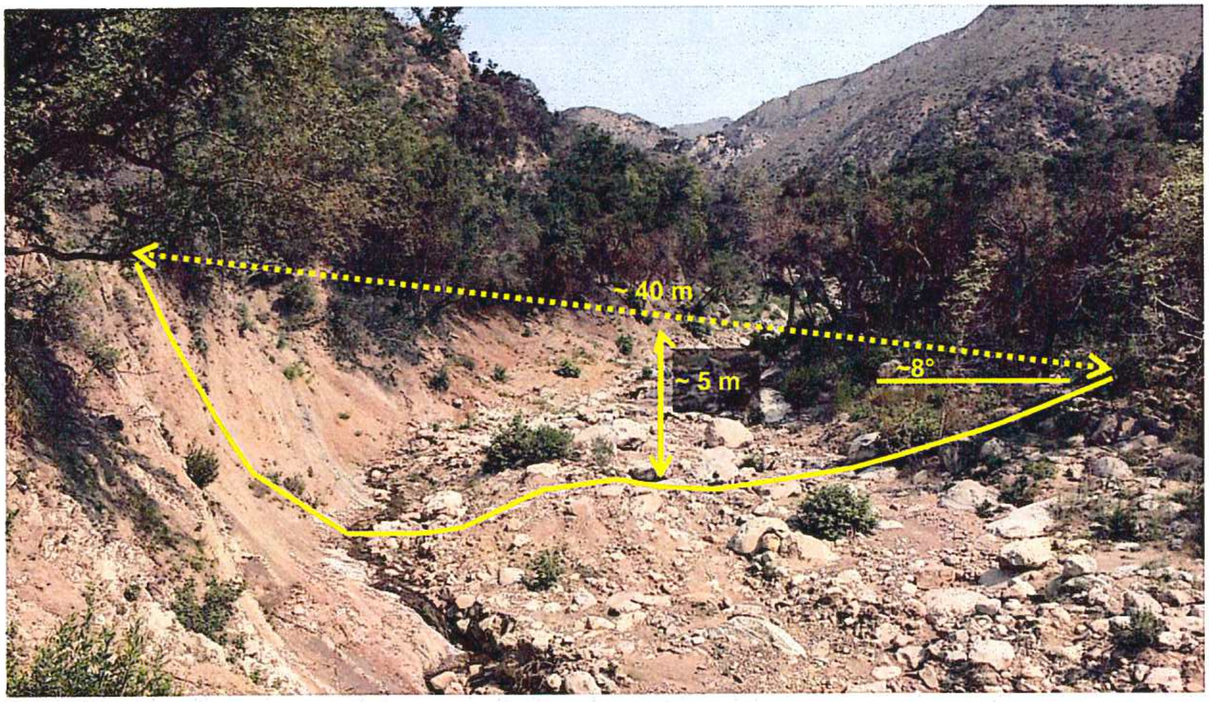

Figure 8. Superelevation of January 2018 flow indicated by mud lines in Cold Spring Canyon approximately 300 m upstream from the development interface. BGC photo, July 2018, looking north.

Figure 9. Destroyed home on San Ysidro Creek, located approximately 1 km from the fan apex. BGC photo, July 2018, looking east.

Figure 10. Woody debris immediately upstream of a destroyed home on Montecito Creek located approximately 2 km from the fan apex. BGC photo, July 2018, looking west.

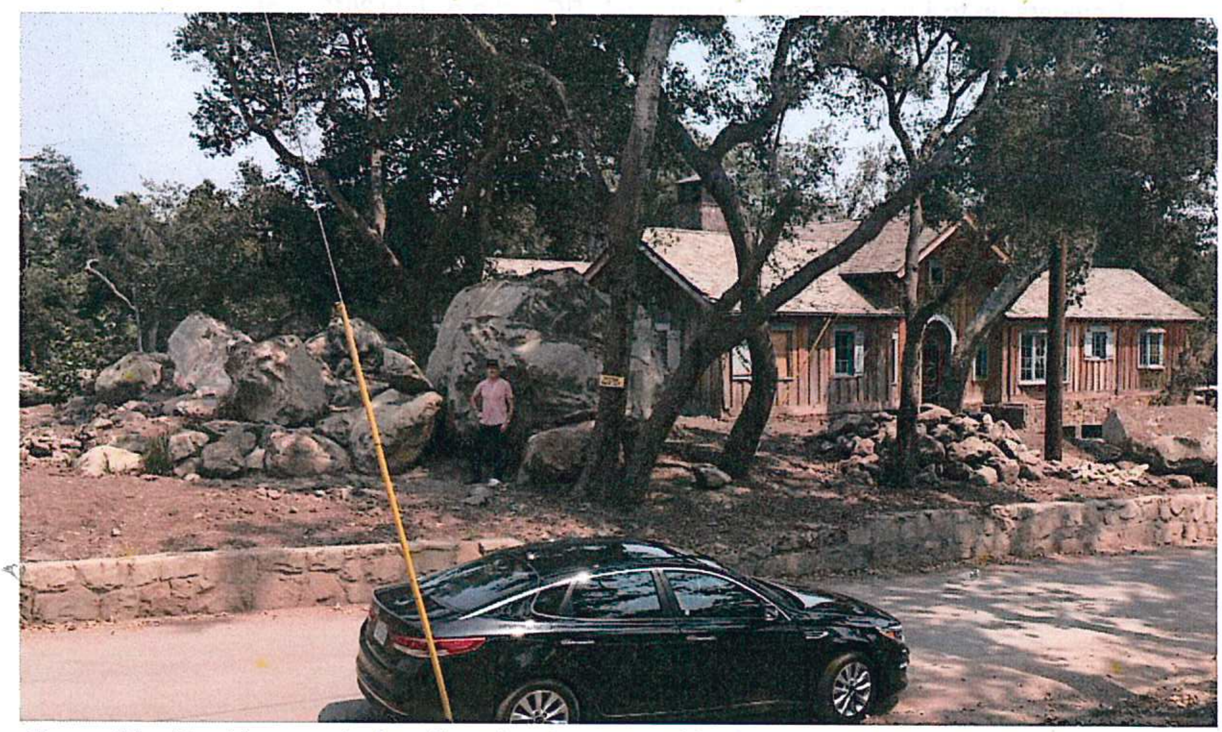

Figure 11. Boulders, up to 4 m diameter, transported by San Ysidro Creek debris flow more than 1 km from the fan apex. BGC photo, July 2018, looking east.

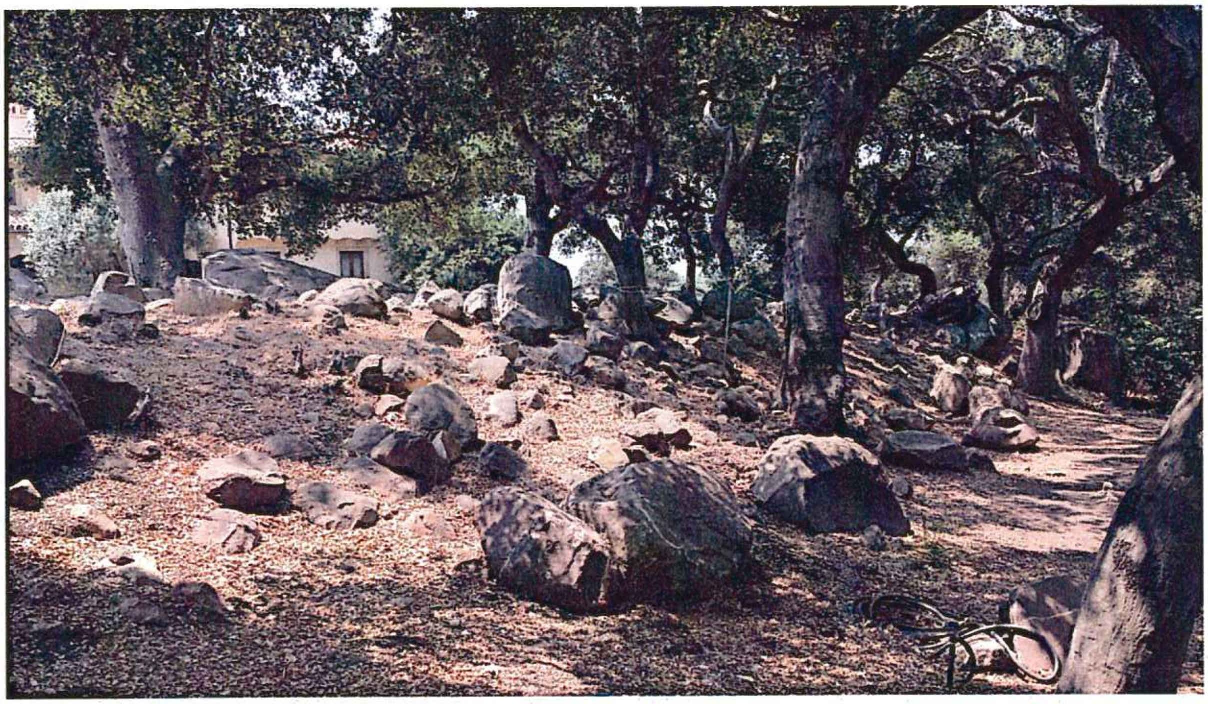

Figure 12. A landform interpreted to be a debris flow levee from an event that pre-dates construction of the home in the background, located 500 m from the Hot Spring Creek fan apex. Boulders up to 1 m diameter in foreground. BGC photo, July 2018, looking south.