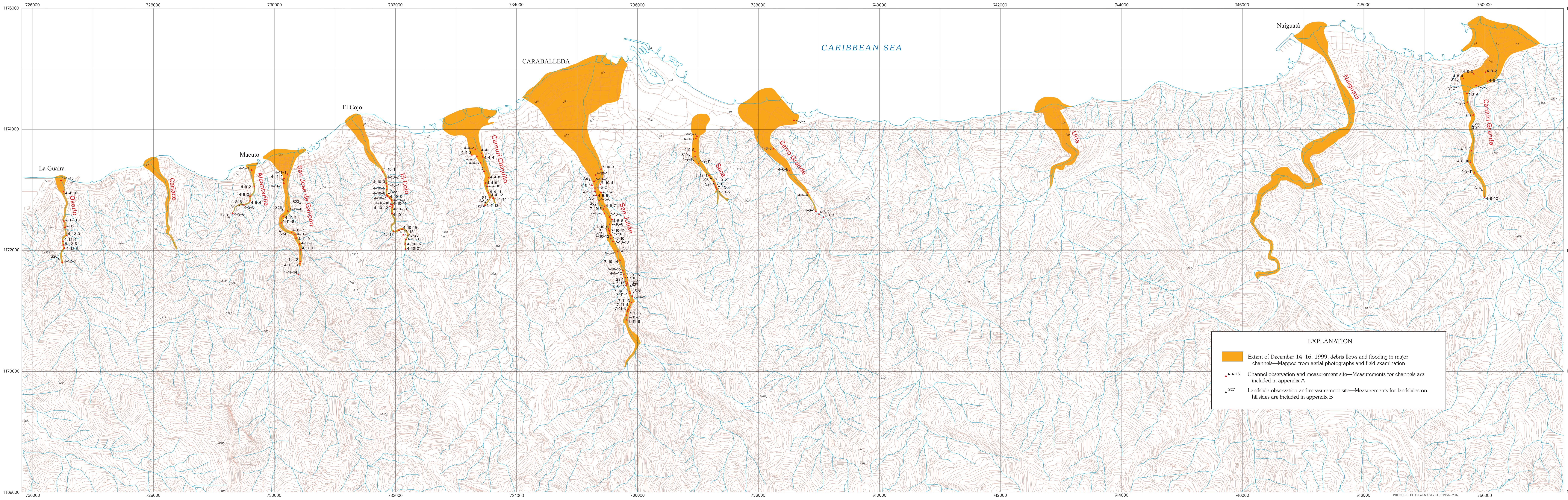


Base from Venezuela Ministry of Environment and Natural Resources
1000-meter Universal Transverse Mercator grid lines, zone 18, datum WGS–84.

SCALE 1:25 000

CONTOUR INTERVAL 20 METERS

INTERIOR–GEOLOGICAL SURVEY, RESTON, VA—2002

Debris flows mapped by G.F. Wieczorek, M.C. Larsen, and L.S. Eaton
Digital compilation by J.L. Blair

Figure 1.—Observation and measurement sites in major channels affected by debris flows and flooding in the December 1999 storm in Venezuela.

APPENDIX A.—MEASUREMENTS OF DEBRIS-FLOW AND FLOOD DEPOSITS

[Map no. refers to field measurement site locations shown in figure 1. Site numbers (for example, 7–10–1) were assigned according to month and day of visit, July 10, and then by order of observation, 1, 2, 3, etc. Site numbers are repeated where separate measurements are made at same site. Location of measurement for depth "left" and "right" refers to location relative to upstream view of channel. Boulder size values of median (50 percent), 75 percent, and 90 percent size distinctions are based on visual estimates. Boulder size values of A, B, and C axes are based on field measurements of maximum boulder(s) at each site. —, indicates no measurements or observations; numbers in red indicate measurements of prehistoric debris-flow deposits; size of boulders referred to within "Comments" indicate length of maximum dimension or "A" axis. A nominal diameter of boulders was calculated from the volume based on the assumption that the boulder was a cube or a sphere. Flow velocity necessary to transport boulders based on boulder size determined by methods of Costa (1983) and Clarke (1996). Flow velocity based on superelevation calculated according to Costa (1984)]

Map no.	Slope, in degrees	Flow depth left, in m	Flow depth right, in m	Deposit thickness, in m	Channel width, in m	Boulder size, in m 50%	Boulder size 75%	Boulder size 90%	Maximum boulder size, in m A axis	B axis	C axis	Volume, in m^3	Nom. diam. cube (sphere)	Superelevation in degrees	Superelevation velocity, in m/s	Flow velocity, in m/s Costa, 1983	Clarke, 1996 cube (sphere)	Comments
Camurí Chiquito																		
4–4–1	3.8–4.0	6.0	4.5	—	95.3	—	—	—	—	—	—	—	—	—	—	—	—	—
4–4–2	2.5–3.0	—	—	—	—	—	—	—	5.1	4.1	2	41.8	3.47 (4.31)	—	—	10.3	6.7 (7.4)	Both schist and gneiss boulders; largest gneiss boulder carried in matrix.
4–4–3	2.5	—	—	—	—	0.4–0.5	—	—	—	—	—	—	—	—	—	—	—	Bus buried with windows intact; laminar deposition around bus; boulders supported by coarse, sandy pebbly matrix.
4–4–4	—	—	—	2.9	—	—	—	—	—	—	—	—	—	—	—	—	—	New debris-flow terrace with minimum thickness of 2.9 m cut by subsequent flooding.
4–4–5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Debris flow from tributary channel leaving deposits atop deposits in main channel.
4–4–6	3.0	—	—	—	—	—	—	—	7.8	7.6	5.0	296.4	6.67 (8.27)	—	—	14.0	9.2 (10.2)	Debris flow moved over top of old house foundation.
4–4–6	—	—	—	—	—	—	—	—	11.3	5.0	3.5	197.8	5.83 (7.23)	—	—	11.4	8.6 (9.5)	—
4–4–7	4.5–5.0	—	—	3.0–4.0	—	1.0–3.0	—	—	—	—	—	—	—	—	—	—	—	Imbricated boulders (maximum dimension of 1 to 3 m) in matrix; debris-flow deposit over flood deposit.
4–4–8	—	8.0	5.5	—	78.0	—	—	—	—	—	—	—	—	2.0–3.0	5.8	—	—	Evidence of a sequence of three events: from top to bottom, coarse debris flow, finer grained debris flow, fine-grained deposition of sediment from flood.
4–4–9	4.5	4.5	—	—	—	—	—	1.5	12.0	8.2	2.4	236.2	6.18 (7.67)	—	—	14.5	8.8 (9.8)	Boulder deposited with top debris-flow event; old debris flow exposed at base of channel with at most 1.5-m-size boulders overlain with brownish-red soil.
4–4–10	7.5	—	—	—	—	1.0	—	—	10.0	4.7	3.5	164.5	5.48 (6.80)	—	—	11.1	8.3 (9.3)	Gneissic boulder; high concentration of large boulders with 1 m average dimension.
4–4–11	4.0–5.0	7.0	12.0	—	54.0	—	—	—	—	—	—	—	—	—	—	—	—	Some large old boulders not removed from bottom of channel; some boulder deposition.
4–4–12	6.0	6.0	9.0	—	27.4	—	—	—	—	—	—	—	—	—	—	—	—	Debris flow entering at junction of major tributary.
4–4–13	13.0–14.0	16.0	10.0	—	17.4	—	—	—	—	—	—	—	—	—	—	—	—	Landslide blocking channel more likely than superelevation of debris flow.
4–4–14	5.0–6.0	9.0	8.0	—	26.0	—	1.0	—	—	—	—	—	—	—	—	—	—	—
San Julián (channel)																		
7–10–1	5.0	3.5	—	3.5	172.0	—	—	—	3.1	2.6	1.0	8.1	2.01 (2.49)	—	—	8.3	5.2 (5.7)	Gneissic boulder.
7–10–1	—	—	—	—	—	—	—	—	3.6	3.0	1.2	13.0	—	—	—	—	—	—
7–10–2	3.0–3.5	—	—	1.7	181.0	—	—	2.5	—	—	—	—	—	—	—	—	—	—
7–10–2	3.0–3.5	—	—	7.0	—	—	—	0.5	—	—	—	—	—	—	—	—	—	Sequence of three old debris-flow deposits with combined thickness of 7 m capped by new deposits.
7–10–3	3.5–5.0	—	—	3.0	111.0	—	—	—	5.3	2.7	1.9	27.2	3.00 (.73)	—	—	8.4	6.3 (6.9)	Gneissic boulder supported in matrix.
7–10–3	—	—	—	—	—	—	—	—	5.9	3.3	1.5	29.2	3.08 (3.82)	—	—	9.3	6.3 (7.0)	Gneissic boulder supported in matrix.
4–5–1	—	—	—	2.5	—	—	0.75	—	—	—	—	—	—	—	—	—	—	—
7–10–4	4.0–5.0	—	—	3.0–6.0	135.0	—	—	—	6.3	2.0	1.9	23.9	2.88 (3.58)	—	—	7.3	6.1 (6.8)	Dark-colored gneissic boulder within a sandy gravel matrix.
7–10–4	—	—	—	—	—	—	—	—	4.4	2.6	1.8	20.6	2.74 (3.40)	—	—	8.3	6.0 (6.6)	—
4–5–2	—	—	—	3.0	—	—	1.0–2.0	—	—	—	—	—	—	—	—	—	—	Central depositional part of channel.
4–5–3	3.0	2.5	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4–5–4	2.5–3.5	1.5	—	—	75.0	—	2.0	—	—	—	—	—	—	—	—	—	—	—
4–5–5	—	—	—	—	—	—	—	—	2.0–3.0	—	—	—	—	—	—	—	—	—
4–5–6	3.0–4.0	—	—	1.0	—	—	—	—	5.6	5.2	3.9	113.6	4.84 (6.00)	—	—	11.6	7.9 (8.7)	—
4–5–6	—	—	—	—	—	—	—	—	5.5	5.2	1.6	45.76	3.58 (4.43)	—	—	11.6	6.8 (7.5)	—
4–5–7	14.0	—	—	—	—	1.20	—	—	3.0–4.0	—	—	—	—	—	—	—	—	Debris flow entering main channel from tributary channel of Quebrada las Choras; debris flows split community of San Julián.
7–10–5	5.5	—	—	>10.0	129.0–145.0	—	—	—	3.0	2.1	1.5	9.5	2.11 (2.62)	—	—	7.5	5.3 (5.9)	Gneissic boulder.
7–10–5	—	—	—	—	—	—	—	—	4.4	4.2	2.5	46.2	3.59 (4.45)	—	—	10.5	6.8 (7.6)	Semi-rounded gneissic boulder deposited near center of channel.
7–10–6	—	—	—	—	145.0	—	—	2.0–3.0	—	—	—	—	—	—	—	—	—	Top of old debris-flow terrace 17.4 m above present-day channel level; 8-cm-thick carbon-rich layer over old debris flow with 2- to 3-m-size boulders at 7.3 m above present-day channel level.
7–10–7	6.0	11.0	—	9.0	140.0	—	—	—	4.8	1.8	1.4	12.1	2.30 (2.85)	—	—	6.9	5.5 (6.1)	Gneissic boulder.
4–5–8	—	—	—	—	—	—	—	—	5.0	2.6	1.0	13.0	2.35 (2.92)	—	—	8.3	5.6 (6.2)	Matrix of debris flow protected under rock; 11 of the largest boulders measured at this location.
7–10–8	5.5–6.0	10.6	—	10.6	75.0	—	—	—	3.6	2.3	1.9	15.7	2.51 (3.11)	—	—	7.8	5.7 (6.4)	Gneissic boulder deposited at constriction point of channel.
7–10–9	4.0	—	—	—	71.0	—	—	3.5	—	—	—	—	—	—	—	—	—	Many boulders greater than 3 m deposited on upper bench of channel.
7–10–10	6.0–6.5	—	—	5.0	98.0	—	—	2.5	6.0	5.3	1.8	57.2	3.85 (4.78)	—	—	11.7	7.0 (7.8)	Old debris-flow terrace on east side of channel with semi-rounded gneissic boulders of 2.5 m deposited about 5 to 7 m above level of present-day channel.
7–10–11	5.5	—	—	6.0	131.0	—	—	—	6.9	4.1	2.9	82.0	4.35 (5.39)	—	—	10.3	7.5 (8.3)	Gneissic boulder.
4–5–9	—	—	—	3.5	—	—	—	—	1.0–2.0	—	—	—	—	—	—	—	—	Islands of bouldery debris-flow deposits incised 2 to 3 m deep by subsequent flooding.
7–10–12	5.0–6.0	—	—	4.0	113.0	—	—	1.5	—	—	—	—	—	—	—	—	—	—
4–5–10	4.0	5.0	12.0	4.0	71.0	—	—	—	2.0–3.0	—	—	—	—	—	—	—	—	Sequence of recent debris flow, flood, debris flow, exposed in 4-m-thick section over old debris-flow deposits; channel eroded to schist bedrock; middle of channel filled with blocky debris.
7–10–13	5.0	5.0	—	4.0	90.0–94.0	—	—	—	9.5	5.9	2.6	145.7	5.26 (6.53)	—	—	12.3	8.2 (9.1)	Dark-banded gneissic boulder supported in matrix; boulder plucked out from nearby outcrop.
7–10–13	5.0	—	—	—	—	—	—	—	6.2	5.8	4.0	143.8	5.24 (6.50)	—	—	12.2	8.2 (9.1)	Boulders supported in matrix of old debris flow.
7–10–13	5.0	—	—	—	—	—	—	—	7.2	6.6	3.8	180.6	5.65 (7.01)	—	—	13.0	8.5 (9.4)	Boulders supported in matrix of old debris flow.
4–5–11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Intact island of old debris-flow deposits topped with recent debris-flow deposits in middle of channel; slightly raised bedrock bench on one side of channel; steep north-dipping foliation in bedrock.
7–10–14	4.0–4.5	12.5	—	4.0	96.0	—	—	—	3.4	2.7	1.6	14.7	2.45 (3.04)	—	—	8.4	5.7 (6.3)	Trim line from flood 12.5 m above present-day level of channel; much higher than trim line from debris flow; gneissic boulder.
7–10–15	4.5	—	—	0.5	55.0	—	—	—	—	—	—	—	—	—	—	—	—	Mostly erosional scour in narrow channel; only thin layer of deposition remaining on high terrace.
4–5–12	2.0–3.0	3.0	3.0	—	95.0	—	—	—	10.4	8.4	4.8	419.3	7.48 (9.29)	—	—	14.7	9.7 (10.7)	Boulder moved(?)—all sides of boulder appear to be fresh and unweathered; some parts of boulder are covered by fresh deposits.
7–10–16	3.5–4.5	12.0	—	>2.0	66.0	—	—	—	8.4	6.4	3.2	172.0	5.56 (6.90)	—	—	12.8	8.4 (9.3)	New 2-m-thick debris-flow deposit atop old terrace.
4–5–13	6.0–7.0	6.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Evidence of debris flows in main and tributary channels . Debris flow in main channel on a slope of 6° to 7° carried the largest boulders; subsequent debris flow from tributary channel on a 15° slope crossed and temporarily blocked main channel.
4–5–14	15.0	—	—	1.5	—	—	—	2.0	—	—	—	—	—	—	—	—	—	Large boulders imbricated over inclined, sandy pre-event(?) surface.
4–5–15	6.0–7.0	—	—	5.0	—	—	—	2.5	—	—	—	—	—	—	—	—	—	Thick bouldery debris-flow deposit incised just below junction of tributary.
7–10–17	7.0	—	—	1.0–3.0	40.0	—	—	—	14.6	13.8	6.5	1309.6	10.90 (13.57)	—	—	18.7	11.6 (12.9)	Old very rounded gneissic boulder at edge of channel; recent deposit, 1 to 3 m thick, plastered against old debris-flow terrace.
7–11–1	6.0–6.5	8.7	—	1.0–1.5	49.0	—	—	—	—	—	—	—	—	—	—	—	—	At western tributary channel, erosional zone with only 1 to 1.5 m of deposition; old 5-m-thick debris-flow terrace of angular to semi-rounded gneissic boulders about 9 m above present-day level of channel.
7–11–2	16.0	—	—	—	—	—	—	—	7.0	5.0	4.0	140.0	5.19 (6.44)	—	—	11.4	8.1 (9.0)	Steep side channel of fault zone(?) near main channel of Río San Julián.
7–11–3	4.5–7.0	10.9	—	1.0	43.0	—	—	—	—	—	—	—	—	—	—	—	—	Erosional section with step-like, irregular topography of bedrock in channel.
7–11–4	—	12.5	—	—	31.0	—	—	—	8.2	5.9	4.0	193.5	5.78 (7.18)	—	—	12.3	8.6 (9.5)	Semi-rounded boulder of augen gneiss; eyewitness reports area was terrace with mangrove trees; pothole eroded into bedrock indicates previous exposure.
7–11–5	5.0–7.0	7.3	—	—	31.0	—	—	—	18.4	11.5	3.5	740.6	9.05 (11.23)	—	—	17.1	10.6 (11.8)	Large boulder moved and jammed into place in steep scoured section of channel with irregular sloped surface.
7–11–6	—	10.0	—	—	34.0	—	—	2.0	—	—	—	—	—	—	—	—	—	Old rounded boulder exposed in debris-flow terrace 14 m above present-day level of stream; multiple bedrock steps in channel.
7–11–7	8.5	12.7	—	—	40.0	—	—	1.5	—	—	—	—	—	—	—	—	—	Main channel completely scoured exposing bedrock; side channels choked with boulders; semi-rounded boulders are seen within old debris-flow terraces.
7–11–8	10.0–14.0	12.0	—	—	18.0	—	—	—	—	—	—	—	—	—	—	—	—	U-shaped channel in bedrock without any remaining deposits.
Cerro Grande																		
4–6–1	5.0–6.0	8.0	—	—	22.1	—	—	—	—	—	—	—	—	12.5	7.0	—	—	Bedrock-controlled channel; channel clean of debris except for that left above terrace.
4–6–2	6.0	17.0	—	—	37.5	—	—	—	—	—	—	—	—	—	—	—	—	Deeply scoured bedrock channel with several old base levels.
4–6–3	3.0–4.0	15.0	—	—	13.7	—	—	0.1	—	—	—	—	—	7.5–8.0	4.2–4.4	—	—	Weir at confluence of tributary; debris flows from both channels; below this point, well-sorted flood deposits; western tributary had U-shaped bedrock channel, with 18° slope in foliated schist.
4–6–4	—	—	—	—	—	—	—	0.2–0.4	—	—	—	—	—	—	—	—	—	Well-sorted flood deposits near quarry.
4–6–5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Flood deposits of sand, gravel, and cobbles in wide channel.
4–6–6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Flood deposits in channel.
4–6–7	—	—	—	2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	At Club Tanaguarena, 0.5 m of slightly clayey, reddish, fine-grained debris flow over 2.0 m of tan fine-grained sediment.
Camurí Grande																		
4–8–1	0.5–1.0	—	—	1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	Overbank sandy flood deposits.
4–8–2	1.0	—	—	—	—	—	—	—	0.2–0.4	—	—	—	—	—	—	—	—	Flood deposits throughout university buildings.
4–8–3	2.0	—	—	0.9–1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	Flood deposits of fine-grained sediment amongst buildings of Simón Bolívar University.
4–8–4	3.0	—	—	1.0–1.2	—	—	—	—	2.7	1.7	0.9	4.1	1.60 (1.99)	—	—	6.7	4.6 (5.1)	Debris-flow deposit covered by sandy flood deposit.
4–8–5	4.5	2.0	—	1.5	—	—	—	—	2.7	2.6	1.5	10.5	2.19 (2.72)	—	—	8.3	5.4 (6.0)	Terminus of debris-flow deposit near old house upstream from the university.
4–8–6	2.5	3.1	—	—	75.0	—	0.7	—	—	—	—	—	—	—	—	—	—	Flood deposits.
4–8–7	2.0–2.5	1.0	—	—	—	—	—	—	4.1	3.6	3.1	45.8	3.58 (4.44)	—	—	9.7	6.8 (7.5)	Only a little sand remaining from a single depositional event without stratification but with some imbrication of small boulders.
4–8–8	2.0	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	A 0.75-m-thick debris flow over a 0.25-m-thick flood deposit; top of debris flow incised by subsequent flood flow.
4–8–9	—	—	—	4.0	—	—	—	—	2.8	1.3	0.8	2.9	1.43 (1.77)	—	—	5.9	4.4 (4.9)	Composite debris flow-flood deposit with sandy matrix; different terrace levels show evidence of three stages of flooding.
4–8–10	2.5	—	—	3.0	—	—	—	—	—	—	—	—	—	—	—	—	—	Large boulders in sandy matrix found at downstream extent of debris-flow deposit.
4–8–11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Incised channel, 25 to 30 m wide and 3 m deep, cut into debris-flow deposits by flood; debris flow from tributary temporarily blocked main channel.
4–8–12	4.0	—	—	6.0	—	—	—	1.0	—	—	—	—	—	—	—	—	—	Sinuous narrow channel.
Alcantarilla																		
4–9–1	4.0	3.2	—	—	—	—	—	0.4	—	—	—	—	—	—	—	—	—	Trim lines show two separate events; deposits indicate two episodes of cobbly debris flow separated by thin layer of fine-grained sand.
4–9–2	4.0	—	—	4.0	—	—	—	—	—	—	—	—	—	10.0	13.6	—	—	—
4–9–3	6.0	1.0	8.0	—	4.5	—	—	—	—	—	—	—	—	11.0–11.5	11.6	—	—	—
4–9–4	—	—	—	—	—	—	—	—	2.7	1.6	1.4	6.0	1.82 (2.26)	0–0.5	3.5	6.5	4.9 (5.5)	—
4–9–5	4.5–4.8	—	—	—	33.5	—	—	—	1.7	1.4	0.8	2.0	1.26 (1.57)	5.0	5.4	6.1	4.1 (4.6)	—
4–9–6	—	—	—	—	—	—	—	—	2.7	2.0	1.9	10.3	2.17 (2.70)	—	—	7.3	5.4 (5.9)	Deposits of boulders in matrix near tributary.
Seca																		
4–9–7	4.0	—	—	—	—	—	—	1.0	—	—	—	—	—	—	—	—	—	At road crossing.
4–9–8	4.0–4.5	—	—	—	—	—	—	2.0	2.4	1.8	0.9	4.1	1.60 (1.99)	—	—	6.9	4.6 (5.1)	—
4–9–8	4.0–4.5	—	—	—	—	—	—	—	3.6	2.7	1.3	12.6	2.33 (2.89)	—	—	8.4	5.5 (6.1)	—
4–9–9	5.0	—	—	—	19.4	—	—	—	5.1	4.2	1.3	27.8	3.03 (3.76)	—	—	10.5	6.3 (7.0)	New boulder deposited over floor tiles from house foundation.
4–9–9	—	—	—	—	—	—	—	—	6.3	4.4	2.0	55.4	3.81 (4.70)	—	—	10.7	7.0 (7.8)	Schistose boulder.
4–9–9	—	—	—	—	—	—	—	—	5.5	3.6	0.8	15.8	2.51 (3.12)	—	—	9.7	5.7 (6.4)	—
4–9–10	4.5	—	—	6.0	—	—	—	2.0	—	—	—	—	—	—	—	—	—	—
4–9–11	8.0	2.0–3.0	—	—	—	—	—	2.0	2.0–3.0	—	—	—	—	—	—	—	—	—
7–13–1	9.0–11.0	5.2	—	3.5	10.0	—	—	—	2.0	1.5	0.6	1.8	1.22 (1.51)	—	—	6.3	4.1 (4.5)	Mostly erosional in this section; 7-m-thick old debris-flow deposit on west bank over saprolite in schist; three bedrock bench levels in channel.
7–13–2	9.0	10.5	—	4.0	26.4	—	—	3.5	7.5	2.7	1.0	20.3	2.73 (3.38)	3.0	3.3	8.4	6.0 (6.6)	A 3- to 4-m-thick blockage of channel by boulders; old debris flow, 5 to 6 m thick, over saprolite exposed in channel bank.
7–13–3	16.0	6.0	—	—	18.0	—	—	—	3.2	2.4	1.0	7.68	1.97 (2.45)	—	—	8.0	5.1 (5.7)	Steep slope alined with bedrock foliation; erosional zone with no deposits.
7–13–4	10.0–12.0	8.7	—	—	21.0	—	—	4.0	1.8	0.9	0.9	1.46	1.13 (1.41)	—	—	4.9	3.9 (4.4)	Thick debris-flow terrace above bedrock channel; recent deposits plastered over old debris-flow terrace.
7–13–5	12.0	8.0–12.0	—	—	12.0	—	—	3.0	—	—	—	—	—	—	—	—	—	Riffle-and-pool eroded bedrock channel; old debris-flow terrace >10 m above present-day level of channel; prominent bedrock bench 1.5 m above present-day level of channel; hillside slopes 40° to 45°.
El Cojo																		
4–10–1	—	—	—	—	—	—	—	1.0–2.0	10.0	7.2	4.6	331.2	6.92 (8.58)	—	—	13.6	9.3 (10.3)	Large boulder in old debris-flow deposit, undercut and collapsed into channel.
4–10–2	5.5–6.0	2.7	—	2.0	—	—	—	—	11.2	—	—	—	—	—	—	—	—	An 11.2-m boulder within a 13-m-thick old debris-flow deposit.
4–10–3	5.0–6.2	3.2	2.8	—	38.0	—	0.5–0.6	—	3.0	1.4	1.2	5.0	1.71 (2.13)	—	—	6.1	4.8 (5.3)	Location of old weir.
4–10–4	—	—	—	2.1	—	—	—	—	2.8	—	—	—	—	—	—	—	—	Just below channel bedrock constriction.
4–10–5	4.5–5.5	—	—	3.6	—	—	—	—	2.5	2.4	1.0	6.0	1.82 (2.25)	—	—	8.0	4.9 (5.5)	Debris-flow deposit of boulders in pebbly sandy matrix over finer grained deposits.
4–10–6	6.5	—	—	3.5	—	—	—	2.3	6.8	3.9	2.9	76.9	4.25 (5.28)	—	—	10.1	7.4 (8.2)	Boulders within pebbly sandy matrix; evidence of log jam >2 m high.
4–10–7	—	2.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	A 2-m-high old debris-flow deposit exposed in channel; ~30-yr-old surviving mango tree with roots wrapped around boulders of old debris flow.
El Cojo—Continued																		
4–10–8	8.0	—	—	2.8	—	—	—	—	4.5	—	—	—	—	—	—	—	—	Base of old tree trunk about 1 m above bottom of incised channel.
4–10–9	8.0	—	—	—	—	—	—	—	6.6	4.0	2.3	60.7	3.93 (4.88)	—	—	10.2	7.1 (7.9)	At junction of channels evidence of tree hit by debris flows from both directions; evidence of debris-flow levee.
4–10–9	—	—	—	—	—	—	—	—	7.8	4.7	3.0	110.0	4.79 (5.94)	—	—	11.0	7.8 (8.7)	—
4–10–10	10.0–10.5	4.4	—	—	17.5	—	—	—	10.0	8.0	—	—	—	—	—	14.3	—	Large, old debris-flow boulder on tributary.
4–10–11	5.0–7.0	—	—	3.0	—	—	0.1	2.0	—	—	—	—	—	—	—	—	—	Two debris-flow events in main channel.
4–10–12	15.0	5.0	—	—	9.0	—	—	2.0	—	—	—	—	—	—	—	—	—	Two debris-flow events in bedrock channel of tributary.
4–10–13	4.0–5.5	3.0	—	—	—	—	—	—	3.0	1.8	1.5	8.1	2.01 (2.49)	—	—	6.9	5.2 (5.7)	—
4–10–14	6.0	6.0	—	—	—	—	—	—	2.5	—	—	—	—	—	—	—	—	Five terraces; uppermost terrace is a debris-flow deposit.
4–10–15	—	—	—	—	—	—	—	—	9.5	6.8	5.1	329.5	6.91 (8.57)	—	—	13.2	9.3 (10.3)	Set of large boulders referred to as "Four Sisters."
4–10–16	—	—	—	—	20.0	—	—	—	6.0	4.6	1.6	44.2	3.53 (4.39)	—	—	10.9	6.8 (7.5)	Gneiss-lined bedrock channel, steeply dipping foliation on channel sides, about 50 m upstream from "Four Sisters."
4–10–17	2.0–3.0	—	—	—	31.4	—	—	—	—	—	—	—	—	4.5–5.0	5.2	—	—	At water intake, radius of curvature = 31.4 m.
4–10–18	6.0	—	4.5–5.0	—	24.0	—	—	—	7.7	2.3	1.2	21.3	2.77 (3.44)	2.5	3.2	7.8	6.0 (6.7)	Radius of curvature = 24 m.
4–10–19	6.0	—	—	—	36.2	—	—	—	—	—	—	—	—	2.5	3.9	—	—	Radius of curvature = 32.6 m.
4–10–20	7.0–8.0	—	—	—	—	—	—	2.0–3.0	8.0	—	—	—	—	—	—	—	—	Recent debris-flow deposit with 2- to 3-m-size boulders in sandy, pebbly matrix; boulder on top of old debris-flow terrace.
4–10–21	7.5	—	—	2.0–3.0	—	—	—	—	—	—	—	—	—	—	—	—	—	Partial blockage of channel by boulders in flat area; boulders within sandy gravel matrix; gneissic bedrock on sides of channel.
San José de Galipán																		
4–11–1	—	5.0	—	4.0	—	—	—	—	—	—	—	—	—	—	—	—	—	From main highway, 100 m upstream in channel.
4–11–2	1.0–1.5	—	—	2.1	—	—	—	—	—	—	—	—	—	—	—	—	—	Overflow channel to the west of main channel; debris-flow deposit over fine-grained fluvial deposit.
4–11–3	2.5	—	—	—	—	—	—	—	3.3	1.6	1.4	7.4	1.90 (2.41)	—	—	6.5	5.1 (5.6)	Boulder in street.
4–11–4	2.0–2.5	—	—	0.5–1.0	—	—	—	—	3.2	2.3	2.3	16.9	2.57 (3.19)	—	—	7.8	5.8 (6.4)	Boulders atop water treatment plant.
4–11–5	4.0	2.0	—	—	—	—	—	—	3.5	2.0	—	—	—	—	—	7.3	—	Upstream in area of widened channel.
4–11–6	4.0–5.0	2.3	—	—	—	—	—	—	3.6	2.4	1.5	13.0	2.35 (2.91)	—	—	8.0	5.6 (6.2)	Recently deposited boulders in sandy matrix; tree bark removed to height of 2.3 m.
4–11–7	6.0	5.1	3.4	—	28.0	—	—	—	—	—	—	—	—	4.0	4.4	—	—	—
4–11–8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Bedrock bench, 6.8 m above present-day level of channel with old boulders on top.
4–11–9	7.0	—	—	—	—	—	—	—	2.5	1.9	0.8	3.8	1.56 (1.94)	—	—	7.1	4.6 (5.1)	—
4–11–10	5.5	—	—	—	—	—	—	—	5.3	2.3	2.3	28.0	3.04 (3.77)	—	—	7.8	6.3 (7.0)	Large boulder within sandy matrix.
4–11–11	—	—	—	7.1	—	—	1.0–1.5	—	7.2	2.0	1.5	—	—	—	—	7.3	—	Boulders in old debris-flow deposit; U-shaped side channel.
4–11–12	4.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Box-shaped channel in bedrock with steep (60°) foliation; old debris-flow terrace exposed in side channel; large amount of old debris-flow material removed from channel.
4–11–13	—	7.6	—	—	3.5	—	—	—	—	—	—	—	—	—	—	—	—	Very narrow, box-shaped channel with steep foliation; bedrock bench, 0.5 to 1.0 m above present-day level of channel.
4–11–14	3.0–4.0	8.0–10.0	—	—	10.0	—	—	—	—	—	—	—	—	—	—	—	—	Water flowing in this channel was slightly turbid.
Osorio																		
4–4–15	—	3.0–5.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Estimated average height of flow between buildings at main highway.
4–4–16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Bouldery deposition in main channel with partially inundated houses.
4–12–1	—	—	—	—	20.0	—	—	—	—	—	—	—	—	—	—	—	—	Damage to houses along channel.
4–12–2	3.0–4.0	4.0	—	—	—	—	—	—	6.7	5.4	1.9	68.7	4.10 (5.08)	—	—	11.8	7.3 (8.0)	Bedrock-controlled channel near Spanish fort at apex of fan.
4–12–3	5.0–5.5	6.3	—	—	21.5	—	—	—	3.2	2.3	1.6	11.8	2.28 (2.82)	9.0	5.8	7.8	5.5 (6.1)	—
4–12–3	—	—	—	—	—	—	—	—	7.0	6.7	2.2	103.2	4.69 (5.82)	—	—	13.1	7.1 (8.6)	Old boulder caught in channel; channel bank exposes 20-m-high debris-flow terrace with large boulders.
4–12–4	—	—	—	—	—	—	—	—	5.7	4.8	2.2	60.2	3.92 (4.86)	—	—	—	7.1 (7.9)	Gneissic boulder left standing on end.
4–12–4	—	—	—	—	—	—	—	—	6.6	4.1	3.0	81.2	4.33 (5.37)	—	—	10.3	7.5 (8.3)	Old boulder moved slightly as indicated by 30° tilt in house foundation built upon boulder.
4–12–5	3.0	5.6	—	—	16.5	—	—	—	8.5	7.5	6.1	388.9	7.30 (9.06)	6.0	4.1	13.9	9.6 (10.6)	Old boulder split into two parts by recent event.
4–12–6	5.0	7.2	—	—	23.8	—	—	—	7.1	4.4	3.5	109.3	4.78 (5.93)	7.0–8.5	5.5	10.7	7.8 (8.6)	Boulder deposited within matrix.
4–12–7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Debris flows came from upper part of drainage above waterfall.
San Julián (Caraballeda fan)																		
7–6–1	3.0–3.5	2.0	—	—	—	—	—	—	2.0	1.5	1.0	3.0	1.44 (1.79)	—	—	6.3	4.4 (4.9)	At eastern end of highway bridge.
7–6–2	4.0	3.5	—	—	96.0	—	—	—	2.9	2.3	2.2	14.7	—	—	—	—	—	Semi-rounded gneissic boulder.
7–6–2	—	—	—	—	—	—	—	—	4.3	2.5	2.1	22.6	—	—	—	—	—	Semi-angular gneissic boulder.
7–6–2	—	—	—	—	—	—	—	—	4.0	3.1	2.1	26.0	2.96 (3.68)	—	—	9.0	6.2 (6.9)	Semi-angular gneissic boulder.
7–6–3	4.0	2.3	—	—	168.0	—	1.3	—	—	—	—	—	—	—	—	—	—	—
7–6–4	3.0	1.0	—	—	128.0	—	—	—	—	—	—	—	—	—	—	—	—	—
7–6–5	2.0–3.0	2.0	—	—	213.0	—	—	—	3.9	3.1	1.6	19.3	2.68 (3.33)	—	—	9.0	5.9 (6.6)	Semi-angular boulder.
7–6–6	4.0	1.7	—	—	79.0	—	—	—	4.0	2.4	2.2	21.1	—	—	—	—	—	Boulders overflowed channel at bend.
7–6–6	—	—	—	—	—	—	—	—	4.1	3.8	3.0	46.7	3.60 (4.47)	—	—	10.0	6.8 (7.6)	Thinning deposits as debris flow spreads at bend in channel.
7–6–7	3.0	3.0–6.0	—	—	434.0	—	—	—	5.3	2.1	1.7	18.9	2.66 (3.31)	—	—	7.5	5.9 (6.6)	Semi-angular boulder.
7–6–8	3.5–4.0	>4.0	—	—	—	—	—	—	5.9	2.8	1.1	18.2	2.63 (3.26)	—	—	8.6	5.9 (6.5)	Tabular boulder.
7–6–9	4.5	4.0	—	—	—	—	—	—	4.1	3.5	1.4	20.1	2.72 (3.37)	—	—	9.6	6.0 (6.6)	Debris flow completely buried first floors of houses.
7–6–10	4.5	5.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fine-grained deposits on top of matrix-supported debris flow.
7–6–11	3.0–3.5	2.0–2.5	—	—	—	—	—	—	6.5	5.7	1.3	48.2	3.64 (4.51)	—	—	12.1	6.9 (7.6)	At intersection with main highway.
7–6–11	—	—	—	—	—	—	—	—	5.0	2.3	1.6	18.4	—	—	—	—	—	Tabular boulder.
7–6–12	3.5	2.5–3.0	—	—	—	—	—	3.0	4.4	3.3	1.6	23.2	2.85 (3.54)	—	—	9.3	6.1 (6.8)	Boulders deposited on high-rise patio; large boulders within matrix deposited above road.
7–6–13	—	—	—	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—	Old debris-flow terrace up to 5 m thick.
7–6–14	4.5–6.0	3.0	—	—	—	—	—	2.0	5.2	—	—	—	—	—	—	—	—	Old debris-flow terrace, 17 m high, displays a sequence of at least four events; yellowish-brown, sandy matrix.
7–6–15	—	—	—	—	—	—	—	—	1.5	—	—	—	—	—	—	—	—	Old debris-flow terrace.
7–7–1	2.5–3.0	1.8–2.5	—	—	—	—	—	1.0	—	—	—	—	—	—	—	—	—	Sequence of three events with a capping debris flow.
7–7–2	3.0–3.5	2.0–2.5	—	—	267.0	—	—	1.0	—	—	—	—	—	—	—	—	—	Sandy gravel deposits.
7–7–3	2.5	1.0–1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Fine-grained sandy deposits with little structural damage.
7–7–4	3.5	1.8–2.0	—	—	—	—	—	—	3.1	2.6	1.4	11.3	—	—	—	—	—	Semi-angular boulder.
7–7–4	—	—	—	—	—	—	—	—	3.9	2.7	2.2	23.2	2.85 (3.54)	—	—	8.4	6.1 (6.8)	Blockage of large boulders and tree trucks protected house downstream.
7–7–5	4.0	2.5–3.0	—	—	238.0	—	—	2.0	—	—	—	—	—	—	—	—	—	Debris blockage.
7–7–6	3.0	0.5	—	—	239.0	—	—	<0.5	—	—	—	—	—	—	—	—	—	Sandy deposits on a side street perpendicular to flow direction.
7–7–7	4.0	2.0	—	—	—	—	—	—	1.8	1.3	0.7	1.6	1.18 (1.46)	—	—	5.8	4.0 (4.4)	Gravelly sand deposits.
7–7–8	5.0–5.5	2.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Old debris-flow boulders incorporated within wall and partially buried in lawn.
7–7–9	2.0–2.5	1.0	—	—	—	—	—	1.0	—	—	—	—	—	—	—	—	—	Old debris-flow terrace >5 m thick with schistose and gneissic boulders.
7–7–10	3.5–4.0	1.5	—	—	—	—	—	<0.5	—	—	—	—	—	—	—	—	—	Little damage to trees along road; impact marks no higher than 0.5 m.
7–7–11	3.5	0.5–1.0	—	—	—	—	—	1.0	2.1	1.3	0.7	1.9	1.24 (1.54)	—	—	5.9	4.1 (4.5)	A few large boulders within coarse-grained sandy deposits; flow through irregular topography in yards between houses.
7–7–12	4.0	2.5	—	2.0	—	—	—	—	5.5	4.2	1.2	27.7	3.02 (3.75)	—	—	10.5	6.3 (7.0)	Flow deposits of very coarse grained sand distributed along street.
7–7–13	5.5	2.0	—	—	—	—	—	2.0	—	—	—	—	—	—	—	—	—	Large boulders filling house and yard causing collapse of wall.
7–7–14	6.0–7.0	2.0–3.0	—	—	—	—	—	1.5	—	—	—	—	—	—	—	—	—	Large boulders supported by sandy matrix.
7–7–15	4.0	1.75	—	—	—	—	—	2.5	—	—	—	—	—	—	—	—	—	—
7–7–16	6.0	2.5	—	—	—	—	—	2.5	—	—	—	—	—	—	—	—	—	Small boulders, 20 to 30 cm in size, in gravelly, sandy matrix that has some laminations.
7–7–17	5.0–6.0	—	—	—	—	—	—	—	2.8	1.3	0.8	2.9	1.43 (1.77)	—	—	5.9	4.4 (4.9)	At Plaza de Piedras, old debris-flow boulders distributed around house built in 1917.
7–7–18	—	—	—	—	—	—	—	—	4.0	—	—	—	—	—	—	—	—	Old schistose, debris-flow boulders exposed in 15-m-high roadcut in red soils.
7–7–19	5.0	3.0	—	—	—	—	—	2.0–2.5	2.5	2.5	2.5	15.6	2.5	—	—	8.1	5.7	Cubed-shaped gneissic boulder.
7–7–20	4.0	—	—	—	—	—	—	—	2.7	—	—	—	—	—	—	—	—	Side channel with 3.5-m-high exposure of three old debris-flow events, with mostly schistose boulders but rare gneissic boulders.
7–7–21	6.0	—	—	—	17.0	—	—	—	1.0	—	—	—	—	—	—	—	—	Side channel with 3-m-high incised box-shaped channel exposing three old debris-flow events; lowest deposit has cemented matrix and gneissic boulders.
7–7–22	5.0–6.0	>2.5	—	—	141.0	—	—	—	2.5	2.0	1.7	8.5	2.04 (2.53)	—	—	7.3	5.2 (5.8)	Along Río San Julián near village of San Julián, a 15-m-high exposure with three units: debris flow, fluvial, and debris flow topped by red soil; lowest unit has tan-colored 2-m-size boulders.
7–8–1	3.0–4.0	—	—	2.5	50.0	—	—	—	4.8	4.4	2.4	50.7	3.70 (4.59)	—	—	10.7	6.9 (7.7)	Along Avenida Principal, one block from old shoreline; coarse-grained, sandy matrix atop gneissic boulders.
7–8–1	—	—	—	—	—	—	—	—	4.8	2.8	1.4	18.8	—	—	—	—	—	—
7–8–2	3.5	—	—	1.7	—	—	—	—	4.5	3.8	1.0	17.1	2.58 (3.20)	—	—	10.0	5.8 (6.4)	Along Avenida Principal, 1/2 block from old shoreline.
7–8–3	1.0	1.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	No boulders found at old shoreline.
7–8–4	1.5	—	—	2.2	—	—	—	—	2.5	1.5	0.8	3.0	—	—	—	—	—	—
7–8–4	—	—	—	—	—	—	—	—	3.8	2.0	1.6	12.2	2.30 (2.85)	—	—	7.3	5.5 (6.1)	Gneissic boulders reached road at old shoreline.
7–8–5	3.5	2.3	—	—	13.0	—	—	—	1.3	0.9	0.8	0.9	0.98 (1.21)	—	—	4.9	3.6 (4.1)	Flow between buildings using road as the channel.
7–8–6	—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Eyewitness reported that large boulders had been removed subsequent to the event.
7–8–7	3.0	1.8–2.0	—	3.4	—	—	—	—	0.9	0.6	0.5	0.3	0.65 (0.80)	—	—	4.1	3.0 (3.3)	Resident reported amount of material removed was 3.4 m thick.
7–8–8	3.0	1.4–1.7	—	—	—	—	—	—	1.6	1.1	0.9	1.6	1.17 (1.45)	—	—	5.5	4.0 (4.4)	Flow traveled between houses.
7–8–9	—	1.4	—	—	—	—	—	—	2.3	2.2	1.2	6.1	1.82 (2.26)	—	—	7.6	4.9 (5.5)	Very irregular benched slope.
7–8–10	2.5–3.5	1.5	—	—	—	—	—	—	3.1	2.0	0.9	5.6	1.77 (2.20)	—	—	7.3	4.9 (5.4)	Gneissic boulder.
7–8–11	3.5	4.2	—	—	—	—	—	—	2.1	1.7	0.8	2.9	1.42 (1.76)	—	—	6.7	4.4 (4.8)	Old debris-flow deposit beneath foundation of crushed house.
7–8–12	—	—	—	2.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7–8–13	3.5–4.5	—	—	>3.0	—	—	—	1.0	3.8	2.9	1.7	18.7	2.66 (3.30)	—	—	8.7	5.9 (6.5)	Bouldery deposit filling first floor of building; 1-m-size boulders deposited atop roof.
7–8–13	—	—	—	—	—	—	—	—	4.8	4.8	2.0	46.1	3.59 (4.45)	—	—	11.2	6.8 (7.5)	Boulder from old debris-flow event; street eroded and served as channel.
7–8–14	4.0	2.5	—	2.0	—	0.75	—	—	3.1	2.4	1.9	14.1	2.42 (3.00)	—	—	8.0	5.6 (6.3)	About 1 m of erosion beneath road level.
7–8–15	—	—	—	—	—	—	—	—	6.0	3.4	1.3	26.5	2.98 (3.70)	—	—	9.4	6.2 (6.9)	Schistose boulder of old debris-flow deposit incorporated within foundation of house.
7–8–16	5.0	—	—	2.0–3.0	—	—	—	—	5.6	4.3	1.7	40.9	3.45 (4.28)	—	—	10.6	6.7 (7.4)	Within a large deposit of boulders, one boulder within matrix rests on steel rebar from building foundation.
7–8–17	2.5	—	—	2.0	—	—	—	3.5	—	—	—	—	—	—	—	—	—	Old 1-m-size boulder in matrix of red soil beneath recent debris-flow deposits; local irregular stepped topography.
7–8–18	3.5–4.0	—	—	1.5	—	1.0	—	—	4.3	3.2	2.5	34.4	3.25 (4.04)	—	—	9.2	6.5 (7.2)	—
7–8–19	4.0	—	—	2.0	—	0.3–0.4	—	—	6.1	3.5	2.6	55.5	3.81 (4.73)	—	—	9.6	7.0 (7.8)	Gneissic boulder is largest within deposit, but schistose boulders also present.
7–8–20	2.5–3.0	—	—	2.0	—	—	—	—	7.2	6.1	1.6	70.3	4.13 (5.12)	—	—	12.6	7.3 (8.1)	Site of partially collapsed apartment house on upper part of fan; schistose boulder collapsed into channel, eroded by late-stage flooding; 3.5-m-size boulders deposited on second floor of structure.
7–8–21	4.0	1.0	—	1.0	—	—	—	1.0	—	—	—	—	—	—	—	—	—	—
7–8–22	4.0	—	—	1.5–2.5	183.0	—	—	—	3.5	3.2	1.9	21.3	2.77 (3.44)	—	—	9.2	6.0 (6.7)	—
7–8–23	4.0	—	—	2.0	—	—	—	—	8.2	6.2	4.1	208.4	5.93 (7.36)	—	—	12.7	8.7 (9.6)	Gneissic boulder oriented with long axis parallel to flow direction.
7–8–24	4.0	—	—	—	64.0	—	—	—	—	—	—	—	—	—	—	—	—	Newly constructed channel with cross-sectional area of 238 m^2.
7–8–25	4.0	—	—	0.4	—	0.1	—	1.0	—	—	—	—	—	—	—	—	—	Fluvial deposition.
7–8–26	—	—	—	—	72.0	—	—	—	—	—	—	—	—	—	—	—	—	Newly constructed channel with cross-sectional area of 261 m^2.
7–8–27	—	2.3	—	1.6	—	—	—	0.2	—	—	—	—	—	—	—	—	—	Fluvial deposition(?).
7–8–28	4.5	—	—	1.9	—	—	—	0.4	—	—	—	—	—	—	—	—	—	Fine-grained deposition of fluvial origin(?).
7–8–29	2.5–3.0	2.0	—	—	—	—	—	1.4	—	—	—	—	—	—	—	—	—	—
7–8–30	3.5–6.0	—	—	3.0	—	—	—	1.2–1.5	—	—	—	—	—	—	—	—	—	Small boulders deposited on roof of one-story building.
7–8–31	4.5	0.8–1.5	—	—	—	—	—	—	2.3	1.7	1.6	6.3	1.84 (2.29)	—	—	6.7	5.0 (5.5)	Gneissic boulder.
7–8–32	4.5	1.8	—	1.8	—	—	—	2.1	2.8	1.8	1.0	5.0	1.71 (2.13)	—	—	6.9	4.8 (5.3)	—
7–8–33	4.5	—	—	2.0	—	—	1.0	—	—	—	—	—	—	—	—	—	—	—
7–8–34	3.0–4.0	—	—	1.8	—	—	—	1.0	—	—	—	—	—	—	—	—	—	—
7–8–35	3.5–4.0	—	—	3.0	—	—	—	—	3.2	2.2	1.7	12.0	2.29 (2.84)	—	—	7.6	5.5 (6.1)	Gneissic boulder; boulder garden in front yard of house.
7–8–36	4.5–5.0	2.3	—	1.8	—	—	—	1.3–1.5	—	—	—	—	—	—	—	—	—	—
7–8–37	—	1.7–1.8	—	1.3	—	—	—	1.0	—	—	—	—	—	—	—	—	—	—
7–8–38	5.0–7.5	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Flood deposition with a few small boulders; eyewitness reported flow of mostly muddy water with a few boulders.
7–10–1	5.0	3.5	—	3.5	172.0	—	—	—	3.1	2.6	1.0	8.1	2.01 (2.49)	—	—	8.3	5.2 (5.7)	Gneissic boulder.
7–10–1	—	—	—	—	—	—	—	—	3.6	3.0	1.2	13.0	—	—	—	—	—	—
7–10–2	3.0–3.5	—	—	1.7	181.0	—	—	2.5	—	—	—	—	—	—	—	—	—	—
7–10–2	3.0–3.5	—	—	7.0	—	—	—	0.5	—	—	—	—	—	—	—	—	—	Sequence of three old debris-flow deposits with combined thickness of 7 m capped by new deposits.
7–12–1	3.0	2.0	—	1.5	—	—	—	—	1.5	1.2	0.9	1.6	1.17 (1.46)	—	—	5.7	4.0 (4.4)	Round boulder punched through two walls of house; house stopped most of debris flow.
7–12–2	3.0–3.5	1.5	—	—	—	—	—	—	1.8	1.3	0.6	1.4	1.12 (1.40)	—	—	5.9	3.9 (4.4)	—
7–12–3	2.5	2.5	—	—	36.0	—	—	—	2.0	1.5	0.5	1.5	1.14 (1.41)	—	—	6.3	3.9 (4.4)	Extension of street used as channel by flow.
7–12–4	3.0	1.9	—	1.9	—	—	—	1.5–2.0	3.0	2.2	1.9	12.5	2.32 (2.88)	—	—	7.6	5.5 (6.1)	Very thin, coarse-grained, sandy matrix with boulder to boulder contact.
7–12–4	—	—	—	—	—	—	—	—	2.7	2.0	1.9	10.3	2.17 (2.70)	—	—	7.3	5.4 (5.9)	—
7–12–5	4.0–4.5	—	—	—	64.0	—	—	—	4.6	2.4	1.5	16.6	2.55 (3.16)	—	—	8.0	5.8 (6.4)	—
San Julián (Caraballeda fan)—Continued																		
7–12–6	6.0	1.8	—	—	—	—	—	—	3.1	2.4	1.7	12.6	2.33 (2.89)	—	—	8.0	5.5 (6.1)	Thickness of deposits decreased as flow moved between houses; some boulders have likely been subsequently removed from streets.
7–12–7	3.5–4.0	1.8	—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	Fine-grained deposition along street.
7–12–8	3.0	1.5	—	—	—	—	—	—	2.0	1.2	0.9	2.2	1.29 (1.60)	—	—	5.7	4.2 (4.6)	—
7–12–9	2.5–3.5	1.4	—	—	—	—	—	—	3.2	3.0	2.8	26.9	3.00 (3.72)	—	—	8.9	6.2 (6.9)	Round boulder.
7–12–10	3.5	2.0	—	1.5–2.0	—	—	—	—	2.0	2.0	1.2	4.8	1.69 (2.10)	—	—	7.3	4.7 (5.3)	Boulders supported by matrix.
7–12–11	2.5	2.5	—	1.7	20.0	—	—	—	—	—	—	—	—	—	—	—	—	—
7–12–12	2.5–3.0	—	—	—	37.0	—	—	—	—	—	—	—	—	—	—	—	—	Minimal amount of flow over bridge, but apparently flow filled channel.
7–12–13	3.0	1.7	—	1.2–1.4	—	—	—	—	1.0	0.9	0.7	0.6	0.84 (1.04)	—	—	4.9	3.4 (3.8)	0.7-m-thick, fine-grained fluvial(?) deposit over 1.7-m-thick bouldery, debris-flow deposit.
7–12–14	2.5	—	—	1.6	—	—	—	—	—	—	—	—	—	—	—	—	—	Uniform coarse-grained, sandy deposit.
7–12–15	2.5	1.8	—	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	All deposits have been removed subsequent to event.
7–12–16	—	—	—	0.7–0.9	—	—	—	—	—	—	—	—	—	—	—	—	—	Deposits decreasing in thickness along length of side street.
7–12–17	1.0–1.5	1.6	—	0.9–1.4	—	—	—	—	—	—	—	—	—	—	—	—	—	Only fine-grained deposits.
7–12–18	1.0	1.0	—	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	Only fine-grained deposits.
7–12–19	—	—	—	—	—	—	—	1.5–2.0	—	—	—	—	—	—	—	—	—	—
7–12–20	3.0–3.5	1.1	—	0.5	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—
7–12–21	3.0	0.5–1.0	—	0.5–1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7–12–22	—	0.8	—	0.6	—	—	—	—	1.6	1.3	0.8	1.6	1.17 (1.45)	—	—	5.8	4.0 (4.4)	—
7–12–23	4.5	0.2–0.3	—	0.2–0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	Only fine-grained deposits.
7–12–24	3.0–5.0	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	Only fine-grained, sandy deposits.
7–12–25	3.0–3.5	1.2–1.5	—	0.8–1.5	71.0	—	—	—	—	—	—	—	—	—	—	—	—	—
7–12–26	3.5	1.0	—	0.4–0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	Sandy deposits.
7–12–27	2.5	—	—	0.8	—	—	—	0.2	—	—	—	—	—	—	—	—	—	Mostly fine-grained deposits.
7–12–28	2.0	0.8–1.1	—	—	—	—	—	1.2	—	—	—	—	—	—	—	—	—	Drilling showed 4.5-m-thick old debris-flow deposits with boulders; only fine-grained deposition in recent deposits at this location.
7–12–29	4.5–5.0	1.1	—	1.0	—	—	—	—	1.3	1.3	0.8	1.4	1.11 (1.37)	—	—	5.9	3.9 (4.3)	Boulders traveled down street which acted like a channel; deposits of imbricated boulders.
7–12–29	—	—	—	—	—	—	—	—	0.9	0.8	0.8	0.5	0.82 (1.01)	—	—	4.7	3.4 (3.7)	—
7–12–30	4.0	1.2	—	0.8	—	—	—	<0.5	1.9	0.8	0.8	1.2	1.07 (1.32)	—	—	4.7	3.8 (4.2)	—
7–12–31	3.5	2.5	—	1.5	—	—	—	—	1.5	0.8	0.7	0.8	0.94 (1.17)	—	—	4.7	3.6 (4.0)	—
7–12–32	3.0–3.5	0.7	—	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7–12–33	5.0–6.0	—	—	—	—	0.99	—	—	3.6	2.8	1.6	16.1	2.53 (3.13)	—	—	—	—	—

APPENDIX B.—LANDSLIDE MEASUREMENTS

[Map no. refers to field measurement site locations shown in figure 1. Slope angle is estimate of original hillside steepness prior to landsliding made by measuring steepness adjacent to flank and scarp of landslide. Width, length, and thickness refer to dimensions of initial landslide source area before transition to debris-flow track. Geologic description refers to description of materials visible in main scarp and base of initial landslide area. Comments include classification of initial landslide movement. —, indicates no measurements or observations]

Map no.	Slope angle, in degrees	Width, in m	Length, in m	Thickness, in m	Volume, in m^3	Geologic description	Comments
Camurí Chiquito							
S1	53	5	15	0.75	56.3	Foliated schist	—
S2	48	8	100	0.5	40	—	Soil slip.
S3	49	5	15	0.5	37.5	Foliated gneiss	—
San Julián							
S4	34–35	25	25–30	2?	1,250	Deep-red soil	Rotational soil slide.
S5	60	5	8	0.2	20	Tan soil over schist	Planar soil slide.
S6	48	5	10	0.3	15	Soil of schist fragments	Debris slide.
S7	30	10	10	1.5	150	Weathered tan schist	Debris slide.
S8	37	30	30	0.5	450	Parallel to foliation in schist	—
S9	39–42	4	3	0.3	3.6	Blocky debris slide	—
S10	—	4	4	0.5	8	Blocky schist	Debris slide.
S27	47	45	259	2.0–3.0	29,138	Mica schist	Removed material to main channel.
S28	53	39	136	1.0–2.0	7,956	Mica schist	Blocky debris slide.
Camurí Grande							
S11	35	20	22	1.0–2.0	660	Deep-red soil	Soil slide.
S12	40	25	25	0.4	250	—	—
S13	38	4	6	1	24	Soil over weathered schist	Soil slide.
S14	42	8	4	0.2	6.4	—	Soil slide.
S15	50	5	20	0.2	20	—	Soil slide.
Alcantarilla							
S16	38–42	18	21	0.55–0.80	255	Blocky colluvium	Reactivated debris slide over weathered bedrock.
S17	30	40	50	4	8,000	Blocky red soil	Block soil slide over gray weathered schist.
S18	—	—	—	—	—	Thin soil over rock	Soil slide.
Seca							
S19	37	19	136	2	5,168	Blocky red soil	Debris slide.
S20	46	39	32	2	2,496	Brown soil over schist	Soil slide.
S21	30	98	200	3	58,500	Rotational soil slide	—
El Cojo							
S22	48	4	10	1	40	Red soil schist fragments	Soil slip within old landslide.
San José de Galipán							
S23	35–37	25	20	2	1,000	Blocky schist	Debris slide.
S24	42–44	8	8	0.7	44.8	Blocky rock	Debris slide.
S25	39	3	5	0.5	7.5	Blocky rock in brown soil	Debris slide.
Osorio							
S26	48	10	10	1	100	Blocky yellow colluvium	Debris slide.

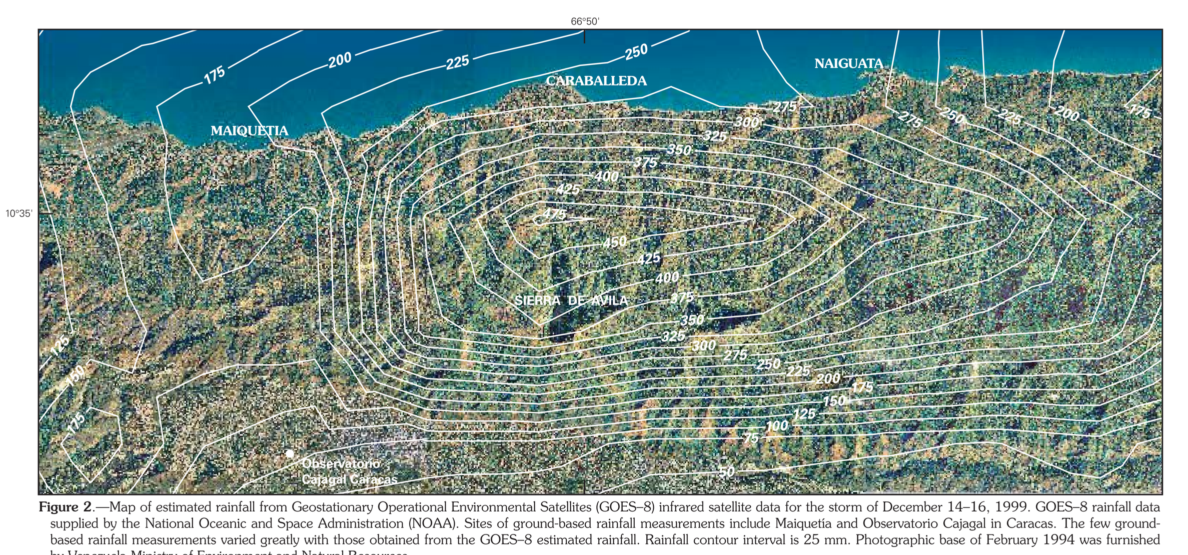
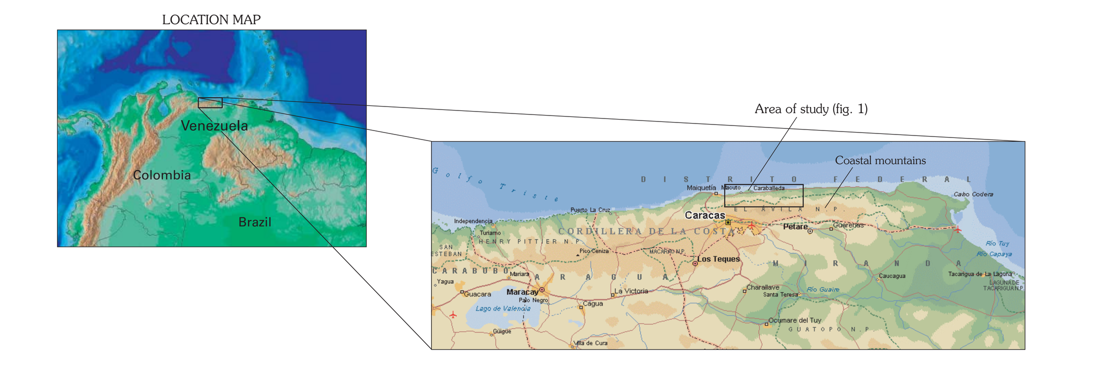


Figure 2.—Map of estimated rainfall from Geostationary Operational Environmental Satellites (GOES–8) infrared satellite data for the storm of December 14–16, 1999. GOES–8 rainfall data supplied by the National Oceanic and Space Administration (NOAA). Sites of ground-based rainfall measurements include Maiquetía and Observatorio Cajagal in Caracas. The few ground-based rainfall measurements varied greatly with those obtained from the GOES–8 estimated rainfall. Rainfall contour interval is 25 mm. Photographic base of February 1994 was furnished by Venezuela Ministry of Environment and Natural Resources.

LOCATION MAP



DEBRIS-FLOW AND FLOODING DEPOSITS IN COASTAL VENEZUELA ASSOCIATED WITH THE STORM OF DECEMBER 14–16, 1999

By

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2002