Alameda Creek Bulk Sediment Study Technical Memorandum

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Introduction

Problem statement

Since construction of the flood control channel on lower Alameda Creek in the 1970s, net sediment deposition has required periodic dredging to maintain flood capacity in the channel. Because dredging is costly, the Alameda County Flood Control and Water Conservation District (the District) has been completing studies to better understand the transport and deposition of sediment within the channel. One of these studies has been complex numerical modeling of the channel system focusing upon water and sediment movement. Because model accuracy is greatly increased when calibrated with field data, and because the grain size distribution of surficial sediment within the channel was identified as a data gap, the District funded this sediment grain size characterization study to support future model interactions.

Study Purpose

SFEI was retained by the District to conduct bulk sediment sampling in the Alameda Creek flood control channel to support future iterations of the 1D/2D sediment transport modeling being carried out by DHI. Samples quantify the grain size distribution of surficial sediment currently present in the flood control channel. The purpose of the technical memo is to report data, with minimal analysis or discussion.

Methods

To ensure that the spatial data collection design was consistent with the current DHI model architecture, Sarah Pearce (SFEI geomorphologist) and David Rupp (DHI modeler) worked closely to develop the initial sampling plan for the 24 bulk sediment samples. The intent of the sampling plan is to ensure that data is collected with an appropriate technical compromise between all influencing factors, such as: 2D model architecture; spatial grain size variations in the cross section, vertically, and longitudinally; patch variation between geomorphic channel features; and tributary influences. Within the reach of Alameda Creek between the mouth of Niles Canyon and the Bay margin, we identified 24 proposed sampling locations aiming to optimize:

- Obtaining samples from each of the three zones defined in the model
- Spacing active channel samples along the entire channel length from Niles Canyon to the Bay
- Obtaining multiple samples along multiple cross section transects to characterize the active channel, low and high bar surfaces, and
- Obtaining a sample(s) upstream of each rubber dam

Once the proposed sampling locations were selected, we worked with Alameda County staff to gain consensus on sample locations before the field work began.

With the initial sampling plan finalized, the field team traveled to the proposed sample locations, using a zoomed-in aerial photograph (individual houses and trees were visible) to locate themselves. Once in the vicinity of the sample location, the team observed the channel for a distance approximately 100m both up and downstream of the proposed location. Based upon visual channel features and best professional judgment, the most representative channel location was chosen for sampling, selecting a riffle whenever possible. Once the general location was chosen, the field team inspected the active channel bed, and identified the most representative patch of sediment. If a portion of the active bed was higher than the water level on that day, but was still comparable in grain size to the bed under water, the field team chose that location for sampling to reduce the loss of fine sediment from flow during sampling. In locations where sampling outside of the water column was not possible, the team used a lightweight metal cylinder (25 cm diameter) pushed into the bed to define the sample location and block flow during sampling.

For each sample location, a 25cm by 25cm square plot was identified and flagged to avoid disturbance. The plot, as well as view up and downstream, was photographed before sampling. Also, the latitude and longitude coordinates were collected using a handheld Garmin personal GPS. If the sample was on a vegetated bar surface, care was taken to remove all of the loose vegetation from the surface. Any plants growing within the sample plot were carefully removed, ensuring that all of the fine sediment trapped in the roots was included in the sample. A visual inspection of the surface pavement was completed, placing large clasts that were more than 50% inside the plot into the sample, and removing those that were less than 50% inside the plot. We aimed to collect enough material so that the single largest clast did not comprise more than 10% (typically not more than 5%) of the total sample weight.

The field team carefully excavated the plot using hand trowels, placing all of the sediment into a clean, labeled five gallon bucket. We did not separate surface and subsurface material (e.g. armor layer); all material was included in the sample container. Each plot was excavated to a depth of 15 cm. It is our judgment that based upon overall grain size distribution and water depths during flood events that this represents the material likely able to be scoured and transported in a medium-sized flood event (e.g. <10 year recurrence interval). Care was taken to keep the walls of the plot vertical, and to excavate to a uniform depth. Samples that were in sand proved difficult; in these cases the depth of the hole was greater than the angle of repose of the sand, causing collapse of the walls. These sample plots ended up being circular, but to a depth of 15 cm. Any water that ended up in the sample container was kept, to avoid losing fines that were in suspension. At the end of excavation, the plot was again photographed. The lid was placed tightly on the sample bucket, and the field team carried the sample out of the channel.

The three furthest downstream samples were in locations where the field team was physically unable to reach via wading. The lowest two samples were in the tidal portion of the channel, with bed material consisting of silt and mud that would not support a person's weight. The third sample is located upstream of the tidal limit, but the water depth in the channel was greater than 1.5m. For these samples a small two-person "mud boat" was deployed from the banks to allow the field team to sample from the middle of the channel. Samples were collected using a petite ponar dredge sampler. The sampler is lowered over the edge of the boat, and when it hits the bed, the jaws close collecting sediment from approximately the upper 3 to 4 cm of the bed. Multiple grabs (between 5 and 10) were required to obtain enough sample material for the laboratory to analyze. Sediment was emptied directly from the sampler into a clean, labeled five gallon sample bucket.

For the locations where three samples were taken along a single channel cross section, the field team surveyed the channel cross section, from levee top to levee top, to characterize the channel geometry, and the elevation of each sample in relation to the channel thalweg. Cross sections were surveyed using a hand level, stadia rod, and measuring tape, with between 20 and 50 points measured for each section.

Samples were sent to Consolidated Engineering Laboratories in Oakland (main contact Bill Coletto 510-434-3016), for grain size sieve analysis. The lab initially requested approximately 10-30 pounds of sediment for each sample, with more material for the coarser samples. Each sample was at least 10 pounds, with most weighing 30-40 pounds, and some weighing up to 70 pounds. Due to a mis-understanding, the lab did not process the entire sample; instead the sample was sub-sampled using a 3" diameter Shelby tube inserted vertically through the sample to "pinch out" a smaller portion. Using this process, a total of approximately 5,000 grams (11 pounds) of material was processed for the coarse samples, and 60 grams (0.13 pounds) for the fine samples. Each sample was dried and sieved using the following sieve sizes: 3”, 1.5”, ¾”, 3/8”, #4, #10, #20, #40, #60, #100, #200. Data is reported as the cumulative weight caught on each sieve, and the percent finer than. In addition, the lab reports the percentage of material in each size category: coarse and fine gravel, coarse medium and fine sand, silt, and clay. The D85, D60, D50, D30, D15, and D10 grain sizes are reported.

The lab requested that we not include clasts that were greater than approximately 50 mm (2 inches). At the four locations were the bed material was larger than 50mm (Samples 10, 12, 13 and 14), those larger clasts were placed into a separate bucket and taken back to SFEI. Here the material was measured and divided into size classes (45, 64, 90, 128 mm) using a grain size template, and each size class was weighed. We intended for these larger clasts to be added to the data returned from the lab, with the grain size distribution adjusted accordingly. Unfortunately, the lab did not weigh the total sample weight, and discarded the un-analyzed portion of the sample for Samples 12, 13, and 14. Therefore we are unable to adjust the reported grain size distribution, and must qualify the data for these three samples as minimums. The lab did weigh Sample 10 (59.9 pounds), and we were able to adjust the distribution. Based upon photographs of each sample container upon completion of sampling, we made our best estimate of total sample weight, and then adjusted the distributions accordingly. We report these estimated distributions separately, noting that they are in fact estimates, and have uncertainties due to the unknown total sample weight.

Results

Each sample was given a unique sample ID, ranging from 1 up to 14, increasing from downstream to upstream (Table 1). Some samples include letters indicating that multiple samples were taken along a single cross section at that location; samples labeled “a” are from the active channel bed, “b” from the low bar surface, and “c” from the high bar surface. Samples span the channel length from San Francisco Bay upstream to the mouth of Niles Canyon (Figure 1). Close up figures of each sample location are shown in the Appendix at the end of this memo (Figures A1 through A7). We report the grain size distributions reported by the lab, including D85 (85% of the sample is finer than this grain size), D50 (the median grain size), D15 (15% of the sample is finer), % finer than 0.25mm (the size distinction between bedload and suspended load), % finer than 0.06 mm (often reported as suspended load), % gravel, % sand, % silt, and % clay (Table 2). We also report our best *estimate* of the grain size distribution for the three furthest upstream samples (Samples 12, 13, and 14) (Table 3). While these should be treated only as estimates, based upon calculations of the range of potential distributions (based upon varying total sample weights), we have much more confidence in the reported D50 and finer values compared to the D85 value. For instance, the D85 value could range by approximately 20mm simply by varying the total sample weight by 4.5 kg (10 pounds). Figure 2 plots the grain size distribution against distance upstream from the Bay; with the exception of sample 6, the reach displays an overall downstream-fining trend. Figure 3 describes the distribution of material in each size class. Generally the downstream reach is dominated by silt and clay, the middle reach is dominated by sand, and the upstream reach is dominated by gravel and sand. Figure 4 plots the fine component (finer than 0.25mm) of each sample. Generally the active bed samples in the fluvial reaches have a very low percentage of this fine material, whereas the low and high bars have a much higher percentage. The exceptions are samples 4, 5, and 9, which may represent deposition of finer material due to a downstream channel constriction. Also, for the cross sectional sample locations, a field survey of the channel cross section and the location of each sample has been plotted (Appendix figures A8-A12).

Table 1. Location of the 24 bulk sediment samples.

Sample	Reach	Location	Position	Longitude	Latitude
1a	Tidal	Between mouth and Ardenwood	Bed	-122.10126	37.56585
1b	Tidal	Between mouth and Ardenwood	Low bar	-122.10141	37.56631
1c	Tidal	Between mouth and Ardenwood	High bar	-122.10118	37.56631
2	Tidal	Upstream of Ardenwood	Bed	-122.06505	37.56861
3a	Fluvial	Downstream of Alvarado	Bed	-122.05702	37.57798
3b	Fluvial	Downstream of Alvarado	Low bar	-122.05573	37.57821
3c	Fluvial	Downstream of Alvarado	High bar	-122.05579	37.57827
4	Fluvial	Between Alvarado and 880	Bed	-122.05134	37.58226
5a	Fluvial	Upstream of 880	Bed	-122.04845	37.58561
5b	Fluvial	Upstream of 880	Low bar	-122.04865	37.58563
5c	Fluvial	Upstream of 880	High bar	-122.04826	37.58536
6a	Fluvial	Dry Creek Tributary Fan	Bed	-122.03928	37.58774
6b	Fluvial	Dry Creek Tributary Fan	Low bar	-122.03926	37.58792
6c	Fluvial	Dry Creek Tributary Fan	High bar	-122.03928	37.58807
7	Fluvial	Upstream of Dry Creek	Bed	-122.03596	37.58704
8a	Fluvial	Upstream of Decoto Road	Bed	-122.02183	37.57597
8b	Fluvial	Upstream of Decoto Road	Low bar	-122.02181	37.57605
8c	Fluvial	Upstream of Decoto Road	High bar	-122.02172	37.57617
9	Fluvial	Upstream of Isherwood	Bed	-122.01123	37.57059
10	Fluvial	Upstream of Rubber Dam #2	Bed	-121.99538	37.56577
11	Fluvial	Upstream of Rubber Dam #1	Bed	-121.98785	37.56953
12	Fluvial	Upstream of Rubber Dam #3	Bed	-121.97164	37.57318
13	Fluvial	Downstream of Mission Blvd	Bed	-121.97086	37.57394
14	Fluvial	Upstream of Mission Blvd	Bed	-121.96868	37.57674

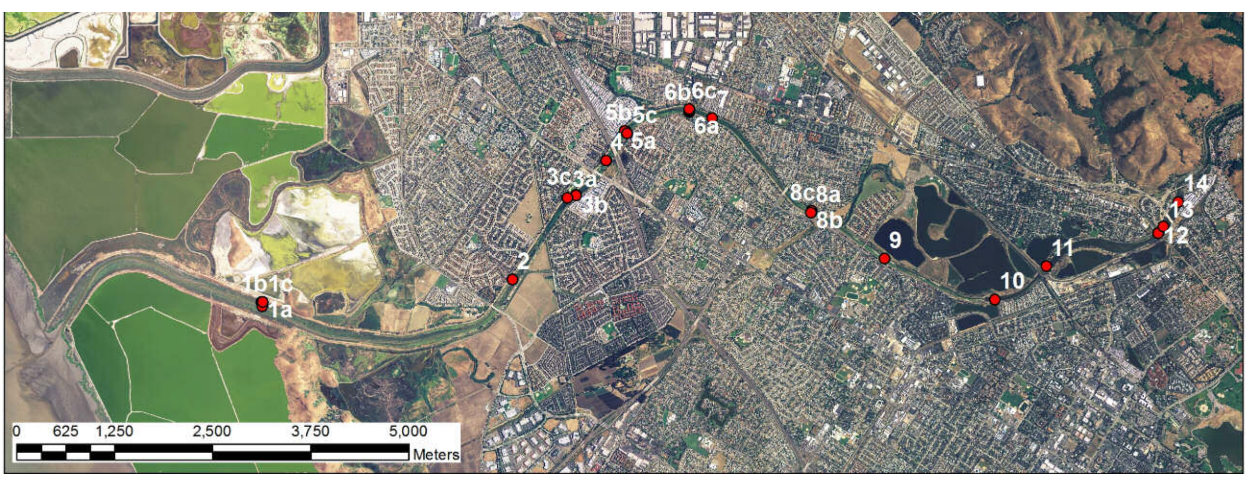

Figure 1. Sediment sampling locations in Alameda Creek Flood Control Channel. See Appendix for close-up images.

Table 2. Bulk sediment sample grain size distribution. D85, D50, and D15 are reported in mm. Samples marked with * are qualified as minimum values; see methods above for discussion.

Sample	D85	D50	D15	%<0.25mm	%<0.06mm	% gravel	% sand	% silt	% clay
1a	0.05	0.01	<0.0015	99.5	93	0	1.5	60.2	38.3
1b	0.09	0.05	0.005	99.7	60	0	23.5	61.4	15.1
1c	0.01	0.002	<0.0019	99.7	98	0	1	32.7	66.3
2	0.03	0.01	<0.0015	94.6	87	0	11	48.4	40.6
3a	0.10	0.04	0.01	93.0	68	0	22.7	70	7.3
3b	0.06	0.02	0.003	97.0	85	0	7.8	69.1	23.1
3c	0.08	0.05	0.01	99.8	65	0	17.3	68.6	14.1
4	6.70	1.02	0.28	11.6	5	24.6	67	8.4	0
5a	4.59	1.02	0.38	12.5	5	14.5	75.6	9.9	0
5b	0.09	0.07	0.02	99.5	40	0	34.2	58.4	7.4
5c	0.20	0.07	0.02	90.2	38	0	46.7	45.3	8
6a	23.76	8.06	0.66	1.3	0	60.4	39.4	0.2	0
6b	0.63	0.34	0.12	34.9	5	0	92	7.6	0.4
6c	1.39	0.26	0.07	48.3	12	0	82.5	16.7	0.8
7	5.95	2.69	1.00	0.2	0	23.2	76.7	0.1	0
8a	9.80	3.07	0.61	2.7	0	35.3	64.3	0.4	0
8b	9.34	3.82	1.22	2.7	0	41.3	57.6	1.1	0
8c	0.10	0.07	0.02	98.2	35	0	35.8	57	7.2
9	6.46	1.12	0.20	18.2	5	21.6	70.8	7.6	0
10	21.90	7.20	1.31	2.3	0	61.0	38.8	0.2	0
11	10.11	3.33	1.33	2.1	0	34.7	64.4	0.9	0
12*	25.77	7.19	0.91	2.8	0	57	42.2	0.8	0
13*	34.56	12.61	1.21	1.9	0	68.7	30.7	0.6	0
14*	27.99	7.79	1.38	0.5	0	59.3	40.5	0.2	0

Table 3. Bulk sediment sample ESTIMATED grain size distributions. D85, D50, and D15 are reported in mm.

Sample	D85	D50	D15	%<0.25mm	%<0.06mm	% gravel	% sand	% silt	% clay
12 Est	90.00	32.00	1.90	1.1	0	45.6	23.1	0.4	0
13 Est	95.00	31.00	3.10	0.8	0	57.5	17.8	0.3	0
14 Est	70.00	12.70	1.70	0.3	0	49.9	34.1	0.1	0

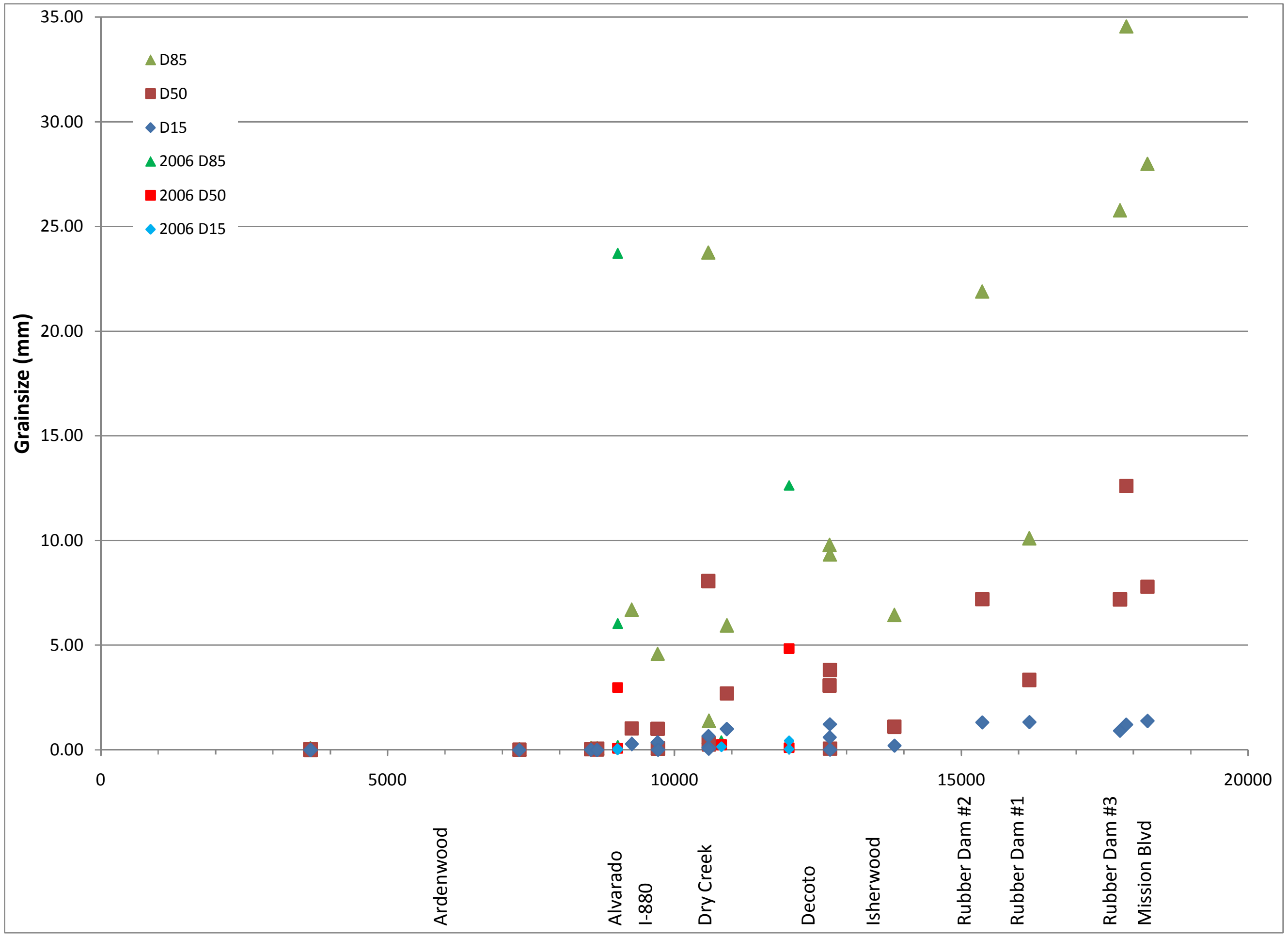

Figure 2. Grain size distribution (D85, D50, and D15) for each sample plotted with channel distance (meters) upstream from the Bay margin. Along the x axis, zero is the mouth of Alameda Creek, and 19,000 meters is approximately the downstream limit of Niles Canyon. This data does NOT include the estimated values for the three furthest upstream samples.

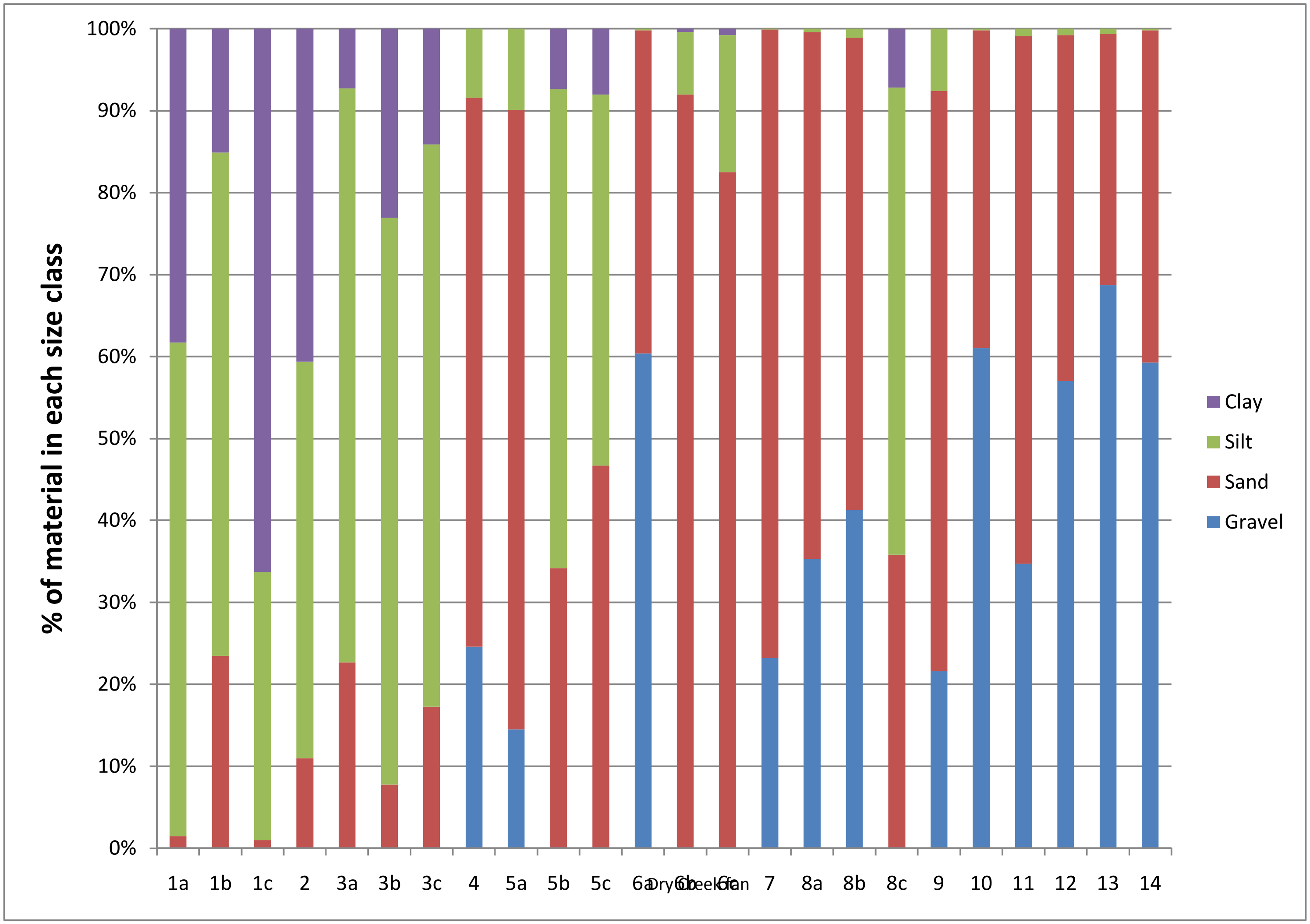

Figure 3. Percent of material in each size class (gravel, sand, silt, clay) for each sample. Note that samples 1 through 3c are dominantly silt and clay; samples 4 through 9 are dominantly sand; and samples 10 through 14 are dominantly gravel and sand. The exception is sample 6a, the active bed sample immediately downstream of Dry Creek, which is dominantly gravel and sand.

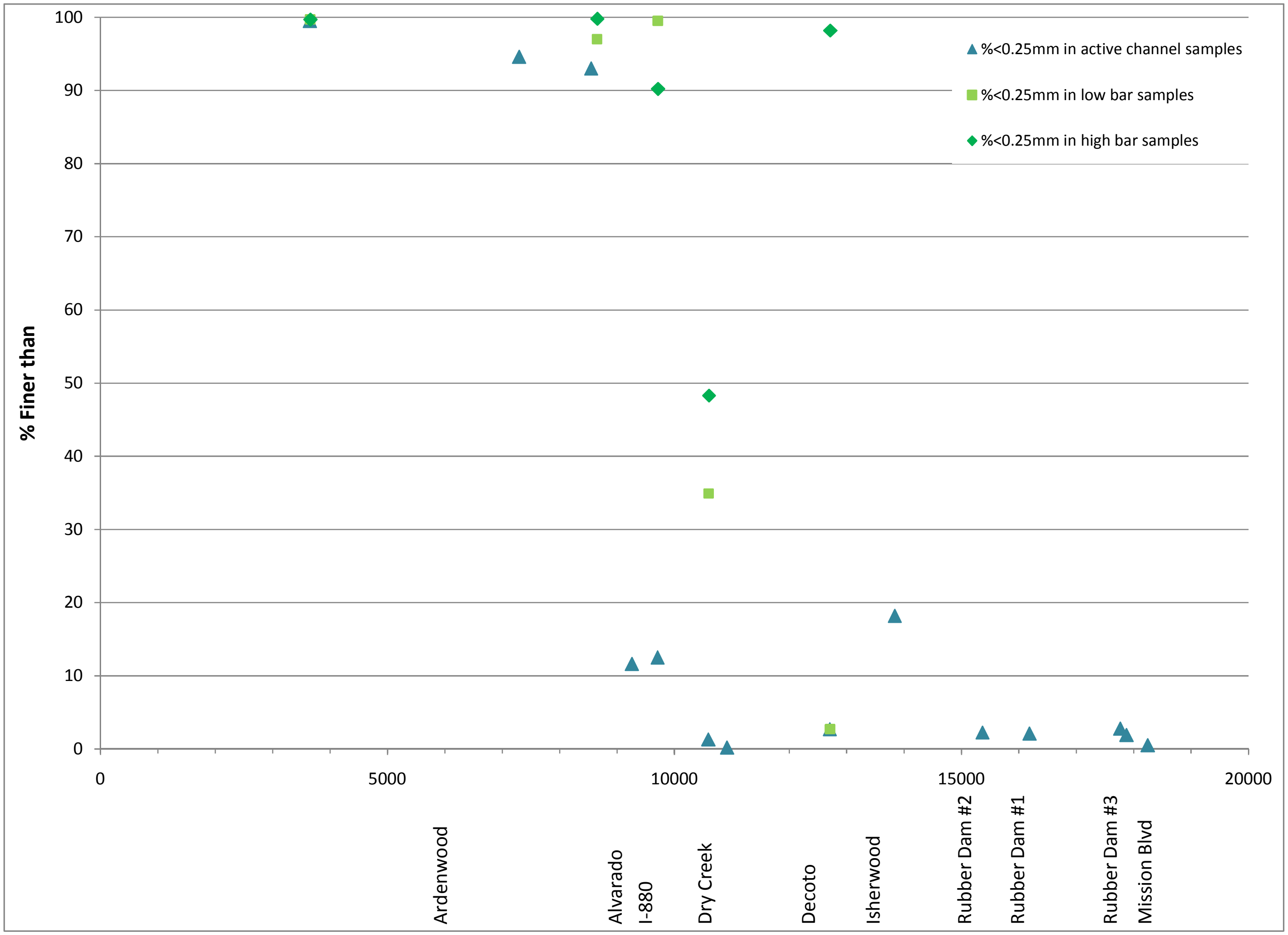

Figure 4. The fine component (finer than 0.25mm) that represents suspended sediment in each sample.

Discussion

Here we briefly discuss details and location of each sample, and the relation to grain size distribution within Alameda Creek.

Sample 1a, 1b, and 1c: These samples are in the tidal portion of the creek, and likely represent a mix of tidal and fluvial sediment. Sample 1b was collected on the back edge of the low-marsh surface, and is slightly coarser than the active bed and the high-marsh samples, possibly due to sediment deposition on this surface at elevated flow levels during small floods or at tidal elevations that are not quite high enough to inundate the higher surface.

Sample 2: This sample was taken along the edge of the active channel using the Petite Ponar, and is likely coarser than the 1a active bed sample because it is higher in the watershed and may receive more fluvial sediment.

Sample 3a, 3b, 3c: These samples are located upstream of the conventional head of tide, however the channel still had many tidal aspects, including the depth of water in the active channel (greater than 1.5 m) and assemblage of plant species. Possibly this location receives tidal water during the extreme winter tides or during storm-related surges. Sample 3b was taken in a small secondary channel on the high-bar surface, and has a slightly finer grain size distribution compared to the other two samples. The active bed sample was taken slightly downstream of the other samples due to access limitations on the bank for putting in the mud boat; visually the channel did not appear to be different in this location.

Sample 4: This sample is taken in the reach between Highway 880 and Alvarado Blvd. In this reach, we encountered an area of harder, more compacted material in the channel bed which may have an impact on sediment deposition or transport. The material appeared to be a layer of clay, although we are not sure if it is fluvial and limited to within the channel, or if it part of the older Quaternary geology of the East Bay Plain. The origin and extent of this layer should be evaluated further in terms of effect upon sediment transport and horizontal and lateral migration of the low flow channel. We hypothesize that this reach may be affected by the constrictions caused by the bridge piers in the channel. While neither Alvarado Blvd or Highway 880 have a concrete bed or extensive abutments, we hypothesize that the in-channel piers have enough hydraulic effect to cause upstream water slowing and thus, deposition of sediment in the adjacent reach.

Sample 5: The grain size distribution of Sample 5a is very similar to Sample 4, with Samples 5b and 5c being finer. We hypothesize that this reach is also affected by the Highway 880 and Alvarado Blvd bridges for the same reasons as described above.

Sample 6a, 6b, 6c: These samples are located on the tributary fan of the Dry Creek tributary. We hypothesize that this feature is caused by deposition of coarser material that is supplied by Dry Creek and that requires a larger flood event to be reworked and transported by Alameda Creek. Sample 6a is taken in a riffle in the active channel, however it is not the most coarse riffle (based upon visual inspection) that exists in this reach. Both the low and high bar surfaces have a larger amount of fine sediment (<0.25 mm) in their distribution, possibly due to contribution of material from Dry Creek, or due to slowing of Alameda Creek velocity at this location allowing deposition of finer material. Sample 6a has a distribution which is similar to that measured closer to the mouth of Niles Canyon. Samples 6b and 6c are dominantly sand, consistent with our field observations.

Sample 7: This sample is taken upstream of Dry Creek, and may reflect sediment deposited due to a backwater effect from the Dry Creek tributary fan which is located downstream from this location.

Sample 8a, 8b, and 8c: These samples are taken upstream of Decoto Road in a reach with larger, less vegetated bar surfaces. Samples 8a and 8b are dominantly sand and gravel, with nearly the same distribution. Sample 8b is likely as coarse as the active bed sample because it represents an active sand and gravel bar deposit. In contrast, Sample 8c is much finer, with a large proportion of material finer than 0.25mm likely because it is located on a remnant surface that is at a higher elevation and densely vegetated.

Sample 9: This sample is in a reach controlled by two upstream concrete weirs. The sample is dominated by sand, and only has approximately 10% of fine sediment. Possibly the weirs are trapping coarser sediment upstream, leaving the reach immediately downstream slightly finer.

Sample 10: This sample is located upstream of Rubber Dam #2, which has not been in operation (the dam has not been inflated) since November 2005 (Thomas Niesar ACWD, pers. comm.). The channel bed was relatively flat, all under approximately 30cm of water. While the grain size was nearly the same across the channel, the sample was taken from the portion of the bed that appeared slightly coarser, closer to the left bank.

Sample 11: This sample was taken upstream of Rubber Dam #1. Our sampling took advantage of the dewatering that occurred to allow construction of a fish passage structure. The channel bed was nearly flat, with a portion of the bed along the left bank slightly higher (about 10 to 15 cm). Two samples were taken: one on the higher surface along the left bank, and the other along the right bank. The right bank sample was analyzed because it visually was coarser. The grain size distribution of this sample is finer than adjacent samples, possibly because this rubber dam is typically in operation, causing a long pool behind it, allowing finer sediment to deposit on top of what may be coarser material at depth.

Sample 12: This sample is located upstream of Rubber Dam #3. Here we were able to take advantage of dewatering for sample collection.

Sample 13: This sample is also upstream of Rubber Dam #3, but is located further upstream. This sample was very indurated, and required considerably more effort to extract the bed material. Although we are not certain why the bed was so indurated, we hypothesize that it is due to deposition of fines during the time period that the rubber dam is in operation.

Sample 14: This sample is located upstream of Mission Blvd, still in the reach typically underwater behind Rubber Dam #3. We hypothesized that this sample would have the coarsest grain size distribution. The sample location was representative of the reach, but did not capture many of the large clasts (90mm up to 300mm) that were scattered across the bed. A larger sample area may reveal a larger grain size distribution, likely larger than what was measured by this sample.

Recommendations

In the context of rising costs associated with continued removal of sediment from the flood control channel, data on the grain size distribution of that sediment is very valuable for multiple purposes. In particular, such field data is essential for sediment transport numerical modeling, and also for analysis and design of alternative channel configurations. To our knowledge, this data (along with data SFEI collected in 2006) represents the only data available on surface grain size of sediment currently in the Alameda Creek flood control channel. The dataset is unique in that it provides data on grain size distribution longitudinally and in a number of cross sections. While the total number of samples is somewhat limited, it provides a great starting point for input into models that describe sediment transport processes in the flood control channel and provides information to support new hypotheses about the role of Dry Creek, channel constrictions and the causes of longitudinal changes in sediment character in relation to channel siltation.

Primarily due to the limited scope of this project, a number of questions remain unanswered regarding sediment deposition within the channel. We recommend that the District focus future work upon:

- **The role of constrictions upon sediment deposition:** Constrictions such as bridges, rubber dams, weirs, and even channel features such as the Dry Creek tributary fan appear to be controlling the location, magnitude, and grain size of deposition. Careful analysis of the detailed longitudinal profile in combination with grain size distribution and previous dredging data will reveal where and what size sediment is being deposited and will be important towards developing a new channel configuration and maintenance schedule that decreases maintenance costs.

- **Contribution of coarse sediment from tributaries other than Dry Creek:** The small, steep tributaries near Niles Canyon (for instance the Masonic Home, Landmark Letters, Niles Reservoir watersheds, Stoneybrook Creek, and even Sinbad and Vallecitos Creeks) could be contributing significant coarse sediment that is being deposited in the Alameda Creek flood control channel. An understanding of relative contributions from each watershed will allow the District to focus future non-point source management efforts in concert with "end of pipe" reach specific solutions in the flood control channel.

- **Distribution of fine (<0.25 mm) sediments:** Via additional sediment sampling in focused locations, the longitudinal distribution of fine sediments (typically carried in suspension) should be characterized. The presence of deposited fine sediment is typically indicative of a "problem" location in terms of sediment transport, and could focus further study upon specific locations. For instance, this data set showed elevated percentages of fine sediment in the samples located upstream of Isherwood, upstream of Highway 880, and downstream of Alvarado in the tidal and tidal backwater locations.

- **Investigation of in-channel clay layer:** The lateral and longitudinal extent of the indurated clay layer observed between Alvarado Blvd and Highway 880 should be mapped. Because this layer appears to be very resistant to erosion, it may have a large effect upon sediment transport and channel configuration in future alternative management scenarios.

Appendix

Figure A1. Close-up of sample number 1.

Figure A2. Close-up of sample number 2. Ardenwood Blvd is in the lower left corner.

Figure A3. Close-up of sample numbers 3 and 4. Sample 3a is located slightly downstream from the other samples because we were unable to deploy the mud boat from the bank immediately adjacent to the cross section. This location was visually similar to that at the cross section. Highway 880 is in the upper right corner.

Figure A4. Close-up of sample numbers 5, 6, and 7. Highway 880 is in the lower left corner.

Figure A5. Close-up of sample numbers 8 and 9. Decoto Road is in the upper left corner.

Figure A6. Close-up of sample numbers 10 and 11. Rubber dam #2 is in the lower left corner.

Figure A7. Close-up of sample numbers 12, 13, and 14. Mission Blvd is in the center.

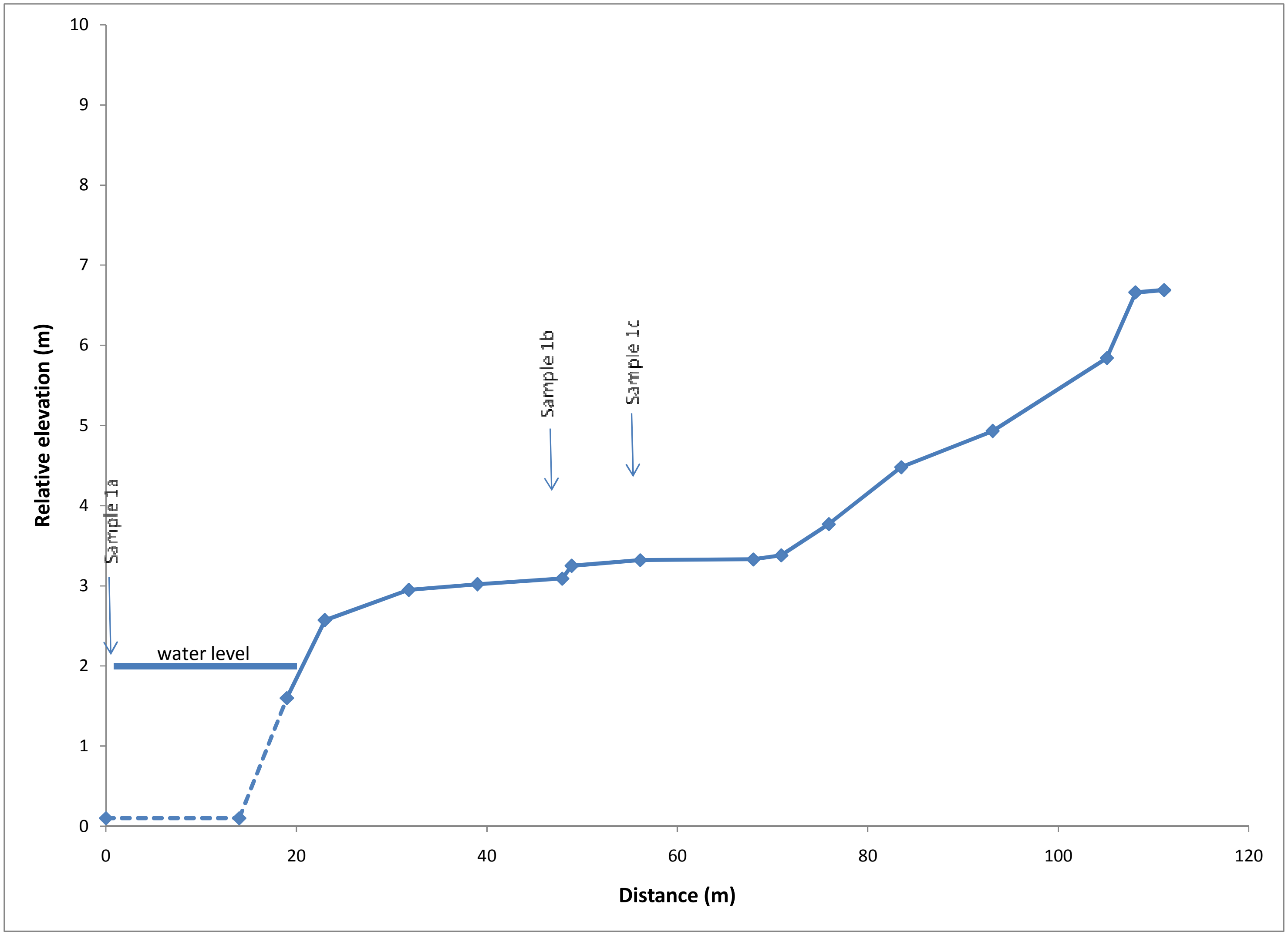

Figure A8. Channel cross section for sample location #1. Note, only one-half of the cross section was surveyed, and channel width is estimated.

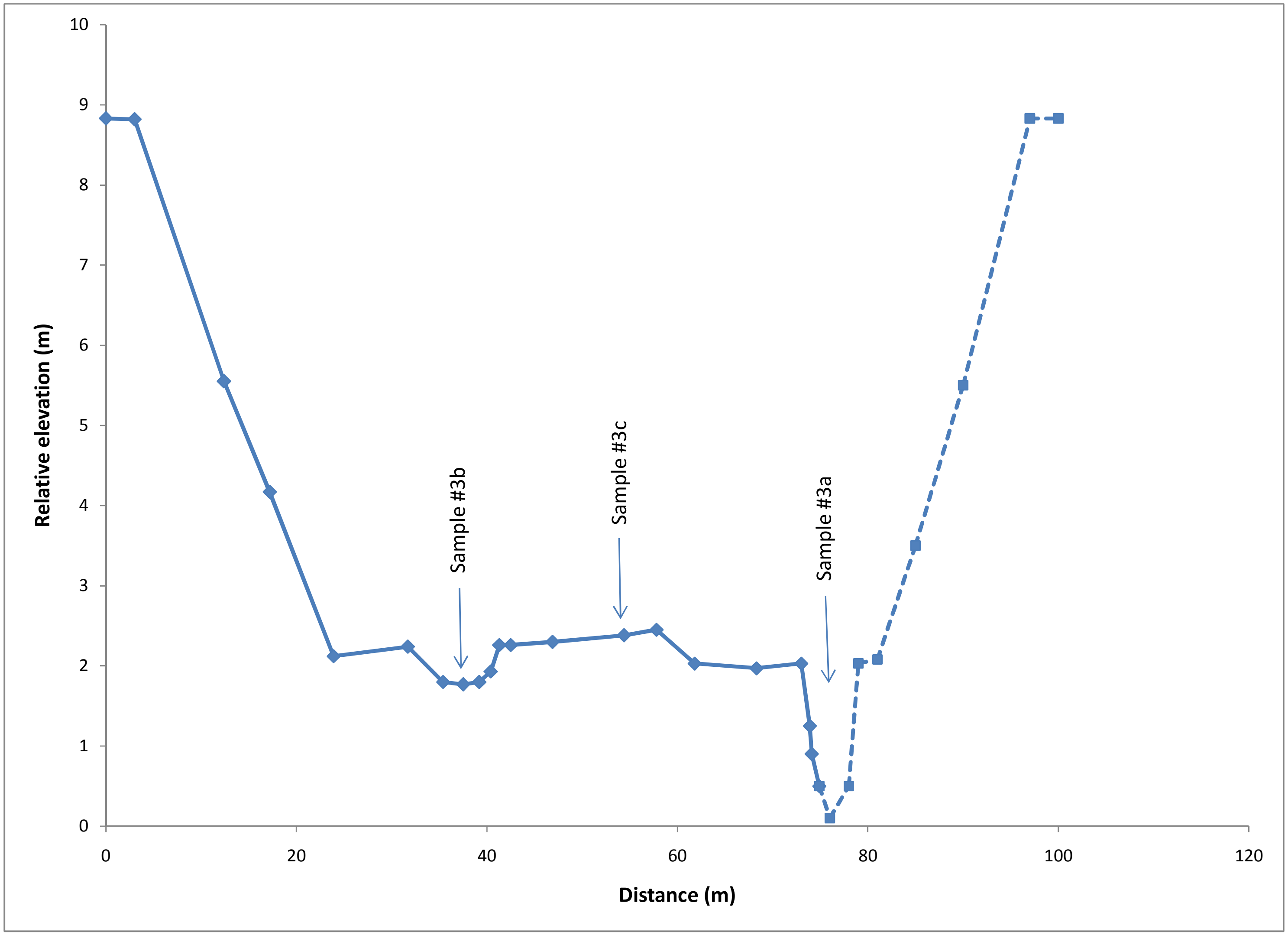

Figure A9. Channel cross section for sample location #3. Dashed line is estimated.

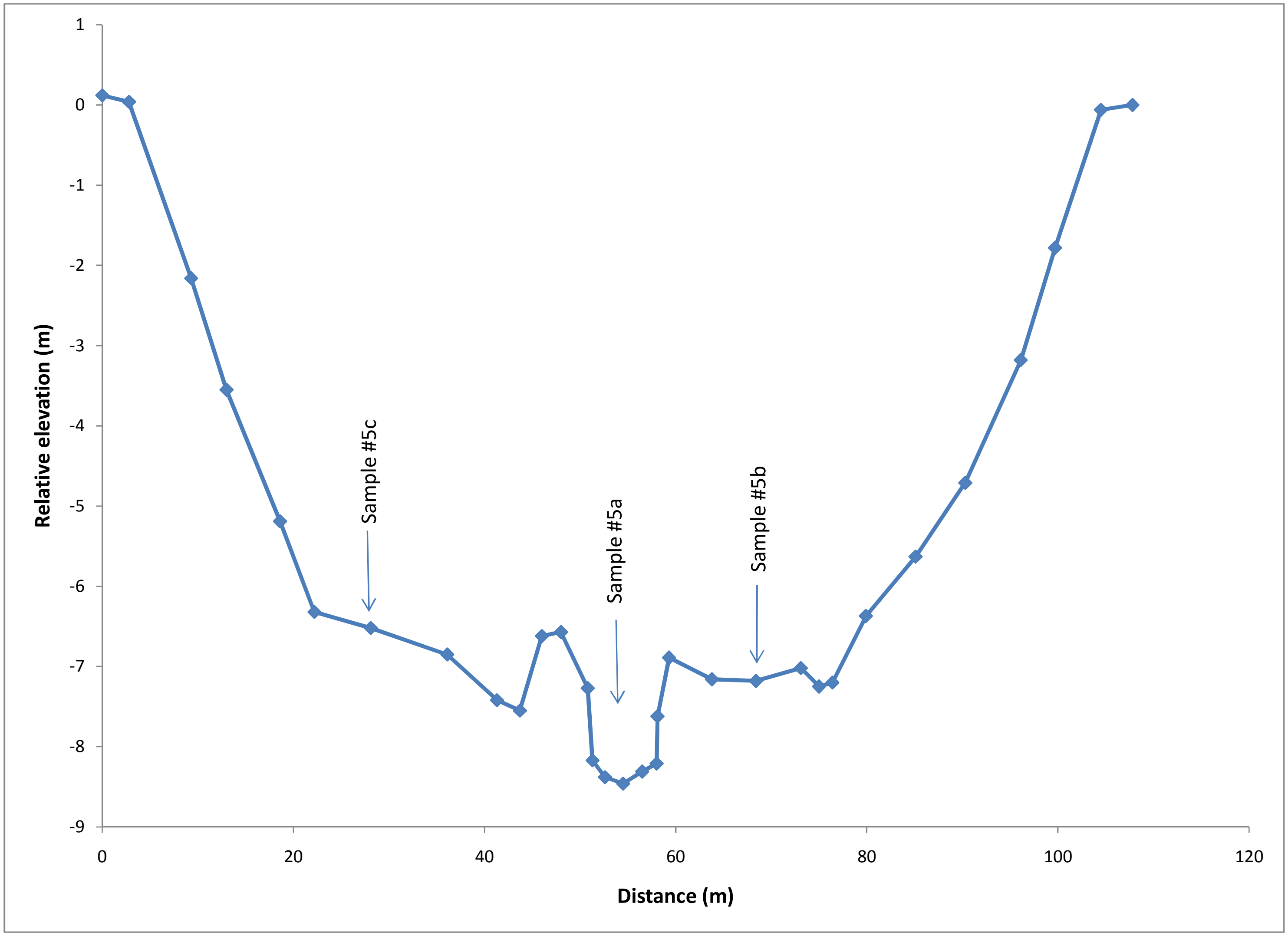

Figure A10. Channel cross section for sample location #5.

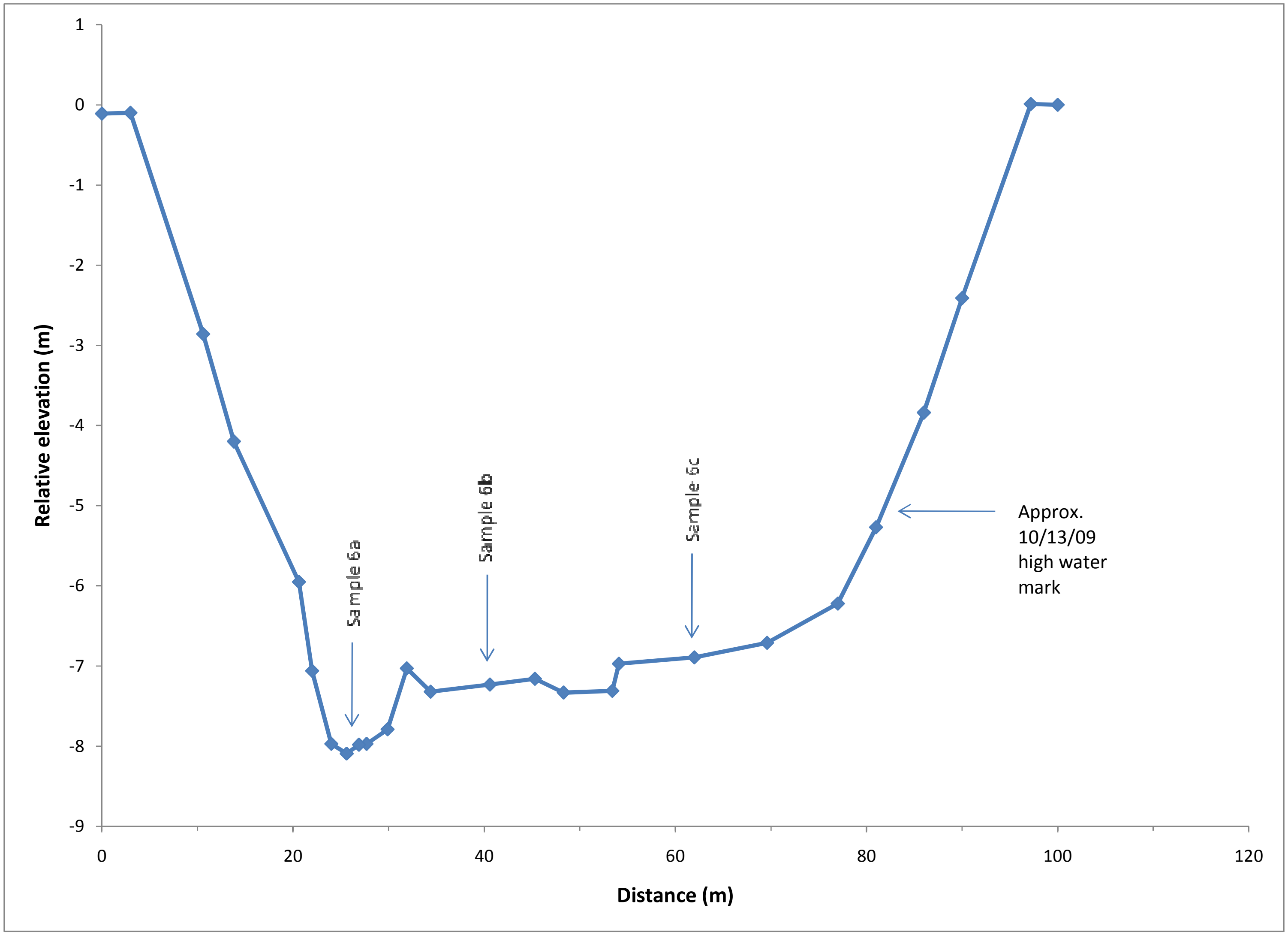

Figure A11. Channel cross section for sample location #6.

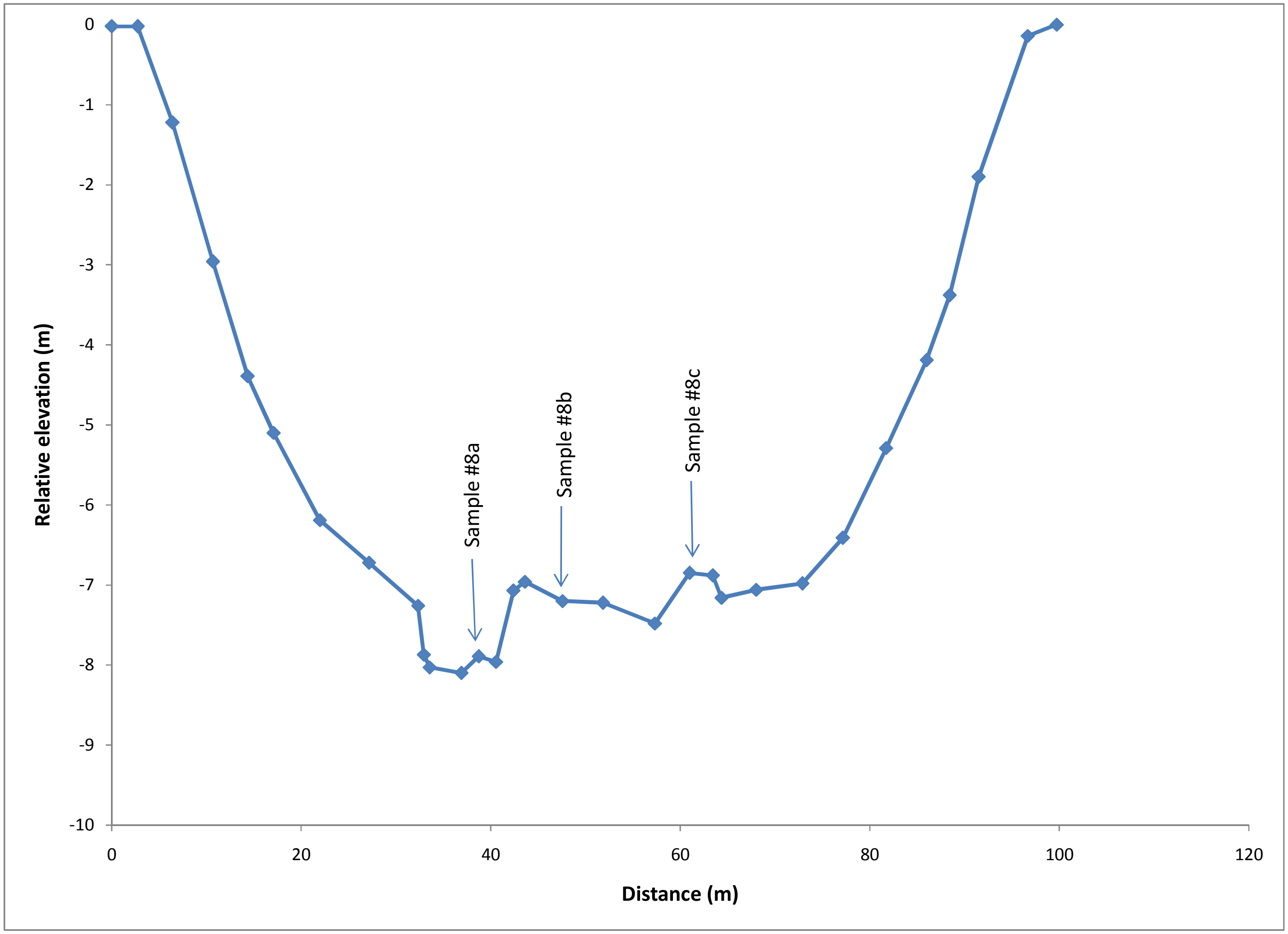

Figure A12. Channel cross section for sample location #8.