Hydrologic Implications of Potential Dam Removals From Baldwin Creek, Cuyahoga County, Ohio

Morgan La Vallee

Department of Geology and Environmental Science

University of Akron

6 May, 2011

Abstract

Dam removal changes the hydrologic parameters in a stream. To measure this, the flow velocity, water depth, water elevation, suspended sediment, and grain size are needed. Once these values are measured, projections can be made by using the fact that discharge equals velocity times area. For Baldwin Creek, the velocities of 0.1835 m/s, 0.1049 m/s and 0.7290 m/s at Transects 1, 2, and 3 respectively, are slow enough to only deposit sediments. Once the dams are removed, the velocities at each transect will increase, allowing the river to transport larger sized particles.

1. Introduction

Three dams on the lower reach of Baldwin Creek in Berea, Ohio have been studied for removal (Figure 1). The present dam structures impede fish passage, causing the water to be poor for fish habitat. Dam 1 is partially breeched, Dam 2 is mostly breeched, and Dam 3 is fully intact (Figure 1). With the removal of one fully intact dam and two partially intact dams, water quality is projected to improve (Rocky River Watershed Program 2011).

Baldwin Creek flows in a north westerly direction with a drainage area of approximately 10 square miles. Seventy-one percent of the watershed area is residential, twenty-four percent is undeveloped, and five percent is commercial and industrial. As a result of urbanization, twenty-six percent of the watershed area is impervious surface, resulting in an increased amount of runoff. The increased runoff causes flashy flows with high sediment loads, producing poor fish habitat (Rocky River Watershed Program 2011).

Dam 1 has a trapezoidal channel and no floodplain. Removing the dam is projected to improve fish migration but not bed diversity (Rocky River Watershed Program 2011). At the

Dam 2 location, the channel is straight and trapezoidal with no floodplain or well, vegetated banks. A structure like a rock cross vane is proposed to be installed to protect the arch culvert from erosion. Dam 3 is four meters tall and is the only dam completely intact. The channel is straight and deep with a low-gradient. The surrounding banks are composed of steep, fine-layered shale, having little vegetation, and are easily eroded. After dam removal, rock step pools or rock cross vanes are proposed to be installed to maintain the current water elevation and still allow fish passage (Rocky River Watershed Program 2011). These structures would maintain a low gradient and low stream velocities, as well as minimize erosion. Moreover, it is proposed to make the right bank should be made more stable by using riprap and sandy loams (Rocky River Watershed Program 2011).

Figure 1. Aerial photograph of the project reach of Baldwin Creek, located in Berea, Ohio (From Rocky River Watershed Program, 2011). The location of the three dams are shown.

This research project investigated the present day hydrologic conditions in Baldwin Creek on March 14, spring 2011, in order to provide baseline data useful in the dam removal planning process.

2.1 Field Methods

River cross sections were measured with a transect and stadia rod. First, we set up the transit and installed a rope across the width of the channel. The cross-section and water depth were measured using a stadia rod (Figure 2). These locations were surveyed, one in the Dam 1 pool and two upstream of Dam 3 (Figure 3). Next, we measured the water surface slope by taking stadia rod readings up and downstream from the cross section location. Then, we measured the water flow at one minute intervals along the rope, using a Gurley Pygmy current meter held 0.4 m off the bottom. Afterwards, we measured suspended sediment using the Ohio sediment stick. Sediment thickness was measured using a metal probe rod (Figure 4), water depth was measured with a meter stick, the latitude and longitude of the samples was measured with a global positioning system, and the temperature of the water measured with an electronic thermometer.

2.2 Laboratory Methods

Loss on Ignition

A 5.28 cc plastic box was completely filled with the fine-grained sediment for each sample. The wet weight was measured and then the sample was dried at 100 c for twenty-four hours and then weighed. Because a known volumes of sediment was used, the wet and dry bulk density was calculated (Table 10).

Grain size

The sediment samples were dried at room temperature and then gently disaggradated by altering grain size. The sediment was weighed and sieved from 64 to 0.0625 mm using a Ro-tap machine for 5 minutes. The weight of sediment on each screen and the mud-sized sediments on the pan was measured. This allowed the grain size distribution of each sample to be determined.

Figure 2. Measuring the river cross-section at transect-1 using a transect and stadia rod.

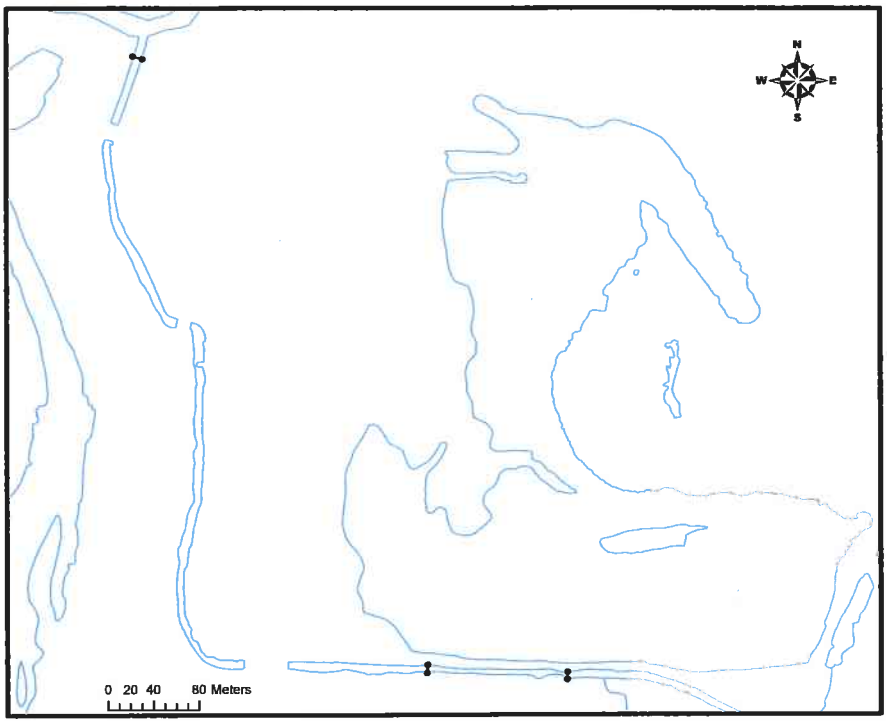

Figure 3. GIS map of the three transect locations in Baldwin Creek of Berea, Ohio.

Figure 4. Measuring water depth and sediment thickness with a meter stick and metal probe rod.

Transect 1 is located in the Dam 1 pool. The data shows a rectangular channel with a consistent velocity away from the banks averaging at 0.1835 m/s (Figure 5). Other measurements from BC-1 are in Table 1. The average slope is 0.000033 m/m (Table 2), the D50 is 0.01425 m and the D84 is 0.0017 m (Table 3). The Calculations (Table 2) include the width (w), depth (d), wetted perimeter (Pw), velocity (v), slope (s), median grain size (D50), large grain size (D84), Reynolds number (Re), Froude number (Fr), shear velocity (U*), bed shear stress (t), shields parameter (O), Reynolds number for particles (Rep), stream power, and relative roughness.

Table 1. River cross section profile, flow velocity, suspended sediment data for Baldwin Creek Transect 1 BC-1 obtained from Dam 1 pool on March 14, 2011.

Stadia Station	Distance on Rope (m)	Top (cm)	Middle (cm)	Bottom (cm)	Distance (m)	Elevation (m)	Water Depth(m)	Velocity (m/s)	Area (m^2)	Discharge (m^2/s)	TSS (mg/l)	Comment
1	-	36.7500	35.7500	35.2500	-1.5	0.8475	-	-	-	-	-	20cm up of rebar/ top of bank
Instrument	-	-	120.500	-	0.00	0.00	-	-	-	-	-	-
2	-	136.50	136.2500	136.00	0.5	-0.28	0	0	0	0	-	water's edge
3	-	177.75	177.50	177.25	0.51	-0.58	0.3	0.0406	0	0	7.3	-
-	-	-	-	-	1	-0.55	0.27	0.0864	0.270	0.0233	-	-
-	-	-	-	-	2	-0.58	0.3	0.2032	0.300	0.0610	-	-
4	3	191.25	189.75	188.25	3	-0.63	0.35	0.2032	0.350	0.0711	-	-
-	-	-	-	-	4	-0.65	0.37	0.1930	0.370	0.0714	-	-
-	-	-	-	-	5	-0.71	0.43	0.2184	0.430	0.0939	-	-
5	-	209.75	206.75	203.75	6	-0.69	0.41	0.2337	0.410	0.0958	-	-
-	-	-	-	-	7	-0.75	0.47	0.1880	0.470	0.0883	-	-
-	-	-	-	-	8	-0.68	0.4	0.1422	0.384	0.0546	-	-
6	8.42	165	160.5	156	8.44	-0.28	0	0	0	0	-	Water's edge
7	-	75.5	70.5	66	8.94	0.5	-	-	-	-	-	rebar
8	-	14	8.75	3.75	9.69	1.1175	-	-	-	-	-	-

Table 2. Hydrologic parameters measured and calculated for Baldwin Creek Transect 1.

w (m)	d (m)	Pw (m)	R (m)	V (m/s)	S (m/m)	D50 (m)	D84 (m)	Re	Fr	U* (m/s)	t (N/m^2)	O	Rep	n	f	Stream Power (watts/m^2)	Relative Roughness
8.42	0.0382	8.4964	0.0379	0.1835	0.000033	0.01425	0.0017	4436.5190	0.2998	0.003501	0.0123	0.0001	32	0.0024	0.0031	0.001	0.0002

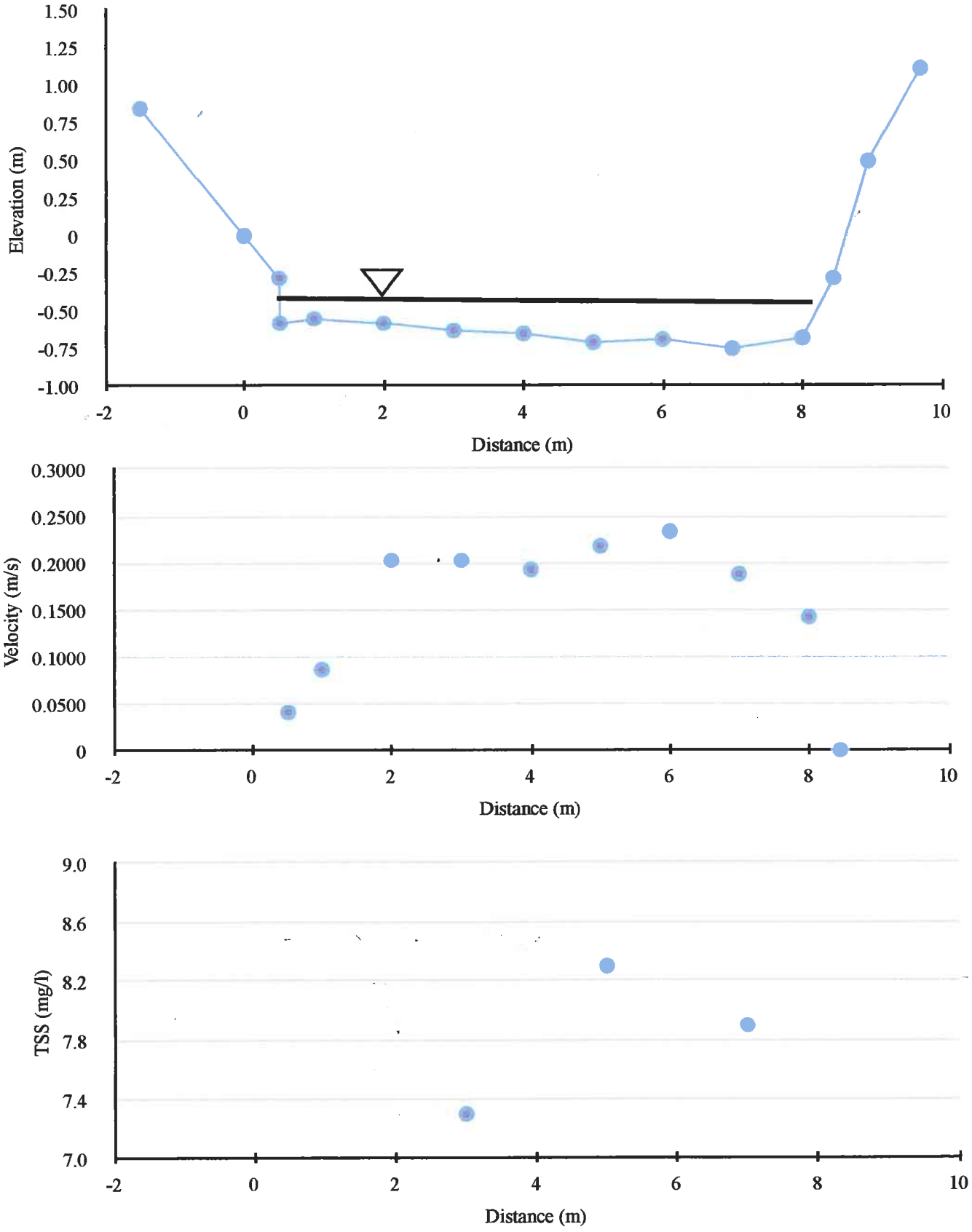

Figure 5. Graphs of the geomorphology (top), flow (middle) and suspended sediment (bottom) collected from Dam 1 transect-1 in the pool of Baldwin Creek on March 14, 2011. Viewed looking downstream.

Table 3. Grain size calculations for Transect 1, Dam 1 pool, sample obtained on March 14, 2011.

					Sample ID	G1					
					Initial wt. (g)	342.051					
					% error	-3.756					
m_ϕ	phi (ϕ)	Individual wt. (g)	Individual wt. %	% G S M	Cumulative wt. %	fm_ϕ	m_ϕ-x	$(m_\phi-x)^2$	$f(m_\phi-x)^2$	$(m_\phi-x)^3$	$f(m_\phi-x)^3$
-6.25	-6	0	0		0	0	-3.868	14.965	0.000	-57.891	0.000
-5.75	-5.5	0	0		0	0	-3.368	11.346	0.000	-38.220	0.000
-5.25	-5	62.126	17.5052127		17.5052127	-91.902367	-2.868	8.228	144.033	-23.602	-413.153
-4.75	-4.5	12.864	3.62468301		21.1298957	-17.217244	-2.368	5.610	20.333	-13.286	-48.158
-4.25	-4	20.584	5.79994365		26.9298394	-24.64976	-1.868	3.491	20.248	-6.523	-37.833
-3.675	-3.35	38.899	10.9605523	70.595	37.8903917	-40.28003	-1.293	1.673	18.337	-2.164	-23.718
-3.175	-3	29.768	8.38771485		46.2781065	-26.630995	-0.793	0.630	5.281	-0.500	-4.190
-2.8	-2.6	11.988	3.37785292		49.6559594	-9.4579882	-0.418	0.175	0.591	-0.073	-0.248
-2.3	-2	28.952	8.15779093		57.8137504	-18.762919	0.082	0.007	0.054	0.001	0.004
-1.75	-1.5	23.803	6.70695971		64.5207101	-11.737179	0.632	0.399	2.675	0.252	1.689
-1.25	-1	21.558	6.07438715		70.5950972	-7.5929839	1.132	1.280	7.778	1.449	8.801
-0.75	-0.5	23.700	6.67793745		77.2730347	-5.0084531	1.632	2.662	17.776	4.343	29.003
-0.25	0	20.668	5.82361229		83.0966469	-1.4559031	2.132	4.543	26.460	9.685	56.400
0.25	0.5	19.441	5.47788109		88.574528	1.36947027	2.632	6.925	37.934	18.224	99.826
0.75	1	19.705	5.55226824		94.1267963	4.16420118	3.132	9.807	54.449	30.710	170.509
1.25	1.5	9.296	2.61932939		96.7461257	3.27416174	3.632	13.188	34.544	47.893	125.448
1.75	2	5.674	1.59876021	29.107	98.3448859	2.79783037	4.132	17.070	27.290	70.524	112.751
2.25	2.5	2.345	0.66074951		99.0056354	1.48668639	4.632	21.451	14.174	99.352	65.647
2.75	3	1.181	0.33276979		99.3384052	0.91511693	5.132	26.333	8.763	135.128	44.966
3.25	3.5	0.682	0.19216681		99.530572	0.62454212	5.632	31.714	6.094	178.601	34.321
3.75	4	0.609	0.17159763		99.7021696	0.64349112	6.132	37.596	6.451	230.521	39.557
4.25	> 4	1.057	0.29783037	0.298	100	1.26577909	6.632	43.977	13.098	291.638	86.859
	TOTAL	354.900				-238.155			466.365		348.481
$mean_\phi$	-2.382										
$\sigma\phi$	2.160										
$SK\phi$	3.485										
D50	-2.575	D84	-4.0719								

Transect 2 is located in the Dam 3 pool. The data shows the channel geomorphology with a range of velocities, averaging at 0.1049 m/s (Figure 6). Other measurements from this transect are in Table 4. The average slope is 0.00000375 m/m (Table 5), the D50 is 0.01019 m and the D84 is 0.01463 m (Table 6). The Calculations (Table 4) include the width (w), depth (d), wetted perimeter (Pw), velocity (v), slope (s), median grain size (D50), large grain size (D84), Reynolds number (Re), Froude number (Fr), shear velocity (U*), bed shear stress (t), shields parameter (O), Reynolds number for particles (Rep), stream power, and relative roughness.

Table 4. River geomorphology, flow velocity, and suspended sediment data for Baldwin Creek Transect 2, BC-11-2 from Dam 3 pool, obtained on March 14, 2011.

Distance on Rope (m)	Top (cm)	Middle (cm)	Bottom (cm)	Distance (cm)	Elevation (cm)	Water Depth (m)	Velocity (m/s)	Area (m^2)	Discharge (m^3/s)	TSS (mg/l)	Comment
Instrument	-	97.5	-	0	0	-	-	-	-	-	Concrete Slab, 1m on rope
4	133.75	132.5	130.75	300	35	-	-	-	-	-	
5.8	228.5	226.25	223.75	475	128.75	-	-	-	-	-	On top of drainage pipe
7.15	337	334	331	600	236.5	0	0	-	-	-	Water's edge
8	-	-	-	700	-	0.045	0.0914	0.0608	0.0056	25.1	
9	-	-	-	800	-	0.0775	0.1575	0.0775	0.0122	-	Clay bottom, concrete slabs
10	407	403.5	398	900	306	0.069	0.1402	0.0690	0.0097	12.7	Gravel
11	-	-	-	1000	-	0.0515	0.1046	0.0515	0.0054	-	Concrete
12	-	-	-	1100	-	0.058	0.1179	0.0580	0.0068	-	Gravel
13	-	-	-	1200	-	0.0455	0.0925	0.0455	0.0042	15	Clay/Gravel
14	-	-	-	1300	-	0.038	0.0772	0.0665	0.0051	-	Clay/Gravel
14.5	-	-	-	1350	-	0.022	0.0447	0.0110	0.0005	-	-
15	-	-	-	1400	-	0.005	0.0102	0.0018	0.0000	16.1	-
15.1	343	336.5	329	1410	239	0	0.0000	-	-	84	-
17	275.5	267.5	259.5	1600	170	-	-	-	-	-	-
Rebar- 18.46	130.75	122.5	113.75	1746	25	-	-	-	-	-	-

Table 5. Hydrologic parameters measured and calculated for Baldwin Creek transect 2.

w(m)	d(m)	Pw (m)	R (m)	V (m/s)	S (m/m)	D50 (m)	D84 (m)	Re	Fr	U* (m/s)	t (N/m^2)	O	Rep	n	f	stream power (watts/m^2)	relative roughness
8	0.0508	8.0748	0.0503	0.1049	0.00000375	0.01019	0.01463	3372.73	0.1486	0.0014	0.0019	0.00001123	8.7756	0.0017	0.0013	0.0002	0.0018

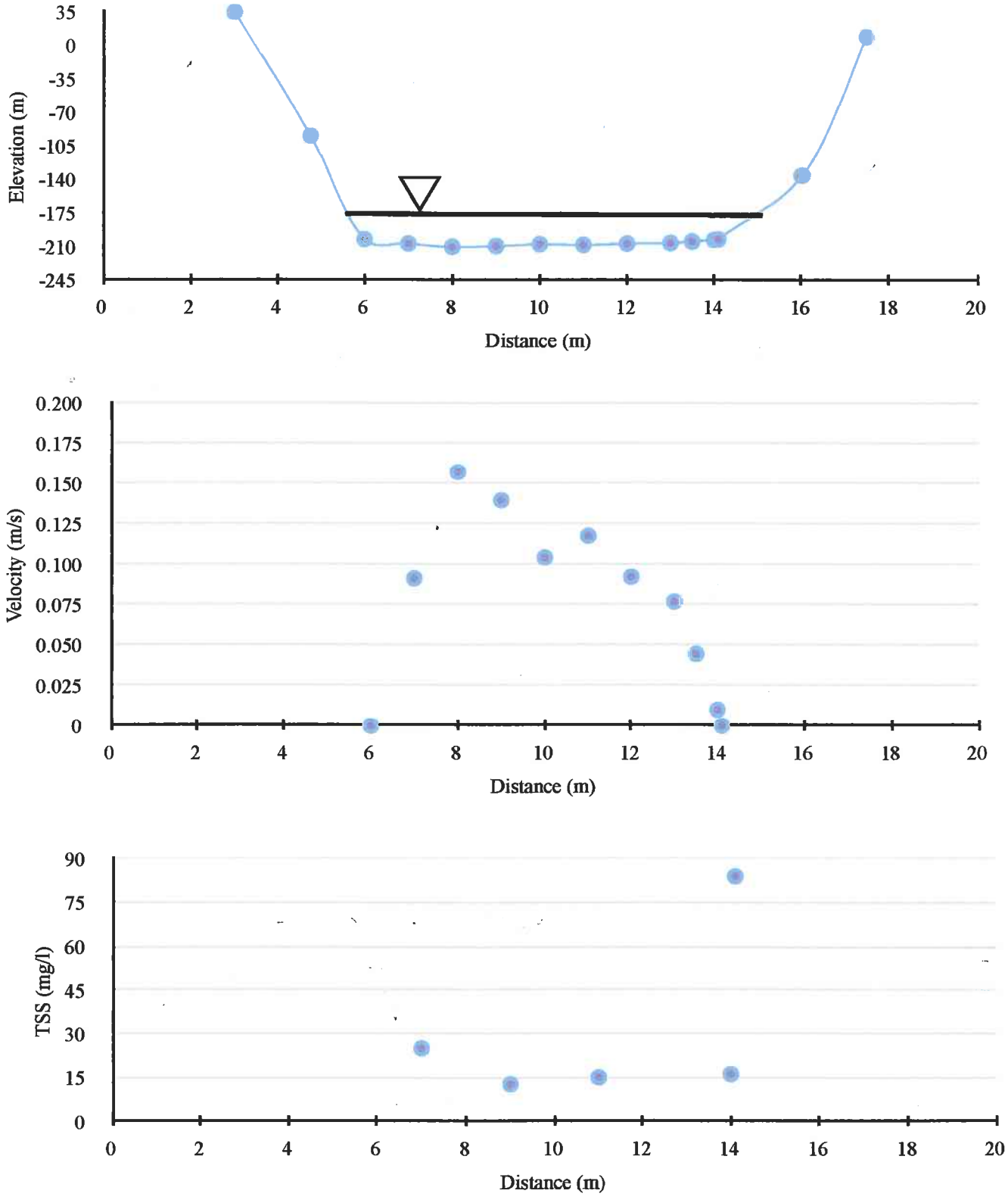

Figure 6. Graphs of the geomorphology (top), flow (middle), and suspended sediment (bottom) collected from Dam 3 transect-2 located in the pool of Baldwin Creek on March 14, 2011. Viewed looking upstream.

Table 6. Grain size calculations for Transect 2, Dam 3 pool, sample obtained on March 14, 2011.

					Sample ID	G15					
					Initial wt. (g)	610.268					
					% error	0.111					
m_ϕ	phi (ϕ)	Individual wt. (g)	Individual wt. %	% G S M	Cumulative wt. %	fm_ϕ	m_ϕ-x	$(m_\phi-x)^2$	$f(m_\phi-x)^2$	$(m_\phi-x)^3$	$f(m_\phi-x)^3$
-6.25	-6	0	0		0	0	-3.340	11.156	0.000	-37.262	0.000
-5.75	-5.5	0	0		0	0	-2.840	8.066	0.000	-22.908	0.000
-5.25	-5	78.815	12.92920312		12.929203119	-67.878316	-2.340	5.476	70.799	-12.814	-165.675
-4.75	-4.5	100.026	16.40876066		29.337963776	-77.941613	-1.840	3.386	55.557	-6.230	-102.229
-4.25	-4	58.560	9.606472558		38.944436333	-40.827508	-1.340	1.796	17.251	-2.406	-23.118
-3.675	-3.35	68.137	11.17753109	81.446	50.121967424	-41.077427	-0.765	0.585	6.542	-0.448	-5.005
-3.175	-3	57.302	9.400104005		59.522071428	-29.84533	-0.265	0.070	0.660	-0.019	-0.175
-2.8	-2.6	22.391	3.673130585		63.195202013	-10.284766	0.110	0.012	0.044	0.001	0.005
-2.3	-2	47.676	7.821007269		71.016209282	-17.988317	0.610	0.372	2.910	0.227	1.775
-1.75	-1.5	37.356	6.128063334		77.144272616	-10.724111	1.160	1.345	8.245	1.561	9.564
-1.25	-1	26.220	4.301258717		81.445531333	-5.3765734	1.660	2.755	11.852	4.574	19.673
-0.75	-0.5	28.125	4.613764356		86.059295689	-3.4603233	2.160	4.665	21.525	10.077	46.492
-0.25	0	21.538	3.533200238		89.592495928	-0.8833001	2.660	7.075	24.998	18.820	66.494
0.25	0.5	16.832	2.761204681		92.353700608	0.69030117	3.160	9.985	27.571	31.553	87.123
0.75	1	15.830	2.596831636		94.950532244	1.94762373	3.660	13.395	34.785	49.025	127.310
1.25	1.5	7.875	1.29185402		96.242386264	1.61481752	4.160	17.305	22.356	71.988	92.998
1.75	2	6.635	1.088438276	17.450	97.330824539	1.90476698	4.660	21.715	23.635	101.190	110.140
2.25	2.5	3.782	0.620418019		97.951242559	1.39594054	5.160	26.625	16.519	137.383	85.235
2.75	3	2.382	0.390755083		98.341997641	1.07457648	5.660	32.035	12.518	181.315	70.850
3.25	3.5	1.265	0.207516868		98.549514509	0.67442982	6.160	37.945	7.874	233.737	48.504
3.75	4	2.108	0.345806765		98.895321274	1.29677537	6.660	44.355	15.338	295.400	102.151
4.25	> 4	6.734	1.104678726	1.105	100	4.69488459	7.160	51.265	56.631	367.052	405.474
	TOTAL	609.589				-290.993			437.611		977.585
$mean_\phi$	-2.910										
$\sigma\phi$	2.092										
$SK\phi$	9.776										
D50	-3.350	D84	-3.8704								

Transect 3 is located upstream of the Dam 3 pool. The data shows the channel geomorphology with a range of velocities, averaging at 0.729 m/s (Figure 7). Other measurements from this transect are in Table 7. The average slope is 0.00007954 m/m (Table 8), the D50 is 0.00365 m and the D84 is 0.0120 m (Table 9). The Calculations (Table 6) include the width (w), depth (d), wetted perimeter (Pw), velocity (v), slope (s), median grain size (D50), large grain size (D84), Reynolds number (Re), Froude number (Fr), shear velocity (U*), bed shear stress (t), shields parameter (O), Reynolds number for particles (Rep), stream power, and relative roughness.

Table 7. River cross section profile, flow velocity, suspended sediment data for Baldwin Creek Transect 3 BC-11-3 upstream of Dam 3 pool, obtained on March 14, 2011.

Distance on Rope(m)	Top	Middle	Bottom	Distance (cm)	Elevation (cm)	Water Depth(m)	Velocity(m/s)	Area (m2)	Discharge (m/s2)	TSS (mg/l)	Comments
Instrument	-	135.00	-	-	-	-	-	-	-	-	-
2.5	137.25	136.25	135.25	200	1.25	-	-	-	-	-	Edge of rock
3	308.25	306.75	305.25	300	171.75	-	-	-	-	-	On shale
4	277.25	275.50	273.25	400	140.50	0	-	-	-	-	Water's edge, Gravel
5	286.25	283.75	281.25	500	148.75	0.0095	0.7264	0.0095	0.0069	-	Gravel/Cobble
6	281.75	278.50	275.75	600	143.50	0.004	0.6350	0.0040	0.0025	15.5	Gravel/Cobble
7	280.00	276.50	273.00	700	141.50	0	-	-	-	-	Gravel/Cobble
8	291.00	287.00	283.00	800	152.00	0.0125	0.7010	0.0125	0.0088	15.5	Gravel/Cobble
9	296.00	291.75	287.50	850	156.75	0.019	0.8788	0.0190	0.0167	-	Gravel/Cobble
10	307.50	302.50	297.75	975	167.50	0.03	0.7976	0.0300	0.0239	15.5	Gravel/Cobble
11	279.00	273.50	268.00	1,100	138.50	-	0.635	-	-	-	Water's edge
11.5	180.00	174.50	168.50	1,150	39.50	-	-	-	-	-	Soil bank
12	149.00	143.00	137.00	1,200	8.00	-	-	-	-	-	Soil bank

Table 8. Hydrologic parameters measured and calculated for Baldwin Creek transect 3.

w(m)	d (m)	Pw (m)	R (m)	V (m/s)	S (m/m)	D50 (m)	D84 (m)	Re	Fr	U* (m/s)	t (N/m^2)	O	Rep	n	f	Stream Power (watts/m^2)	Relative Roughness
7	0.012	7.024	0.012	0.729	0.00007954	0.00365	0.0120	5,536.709	2.1795	0.0031	0.0093	0.0002	7.0571	0.0004	0.000123	0.1115	0.0017

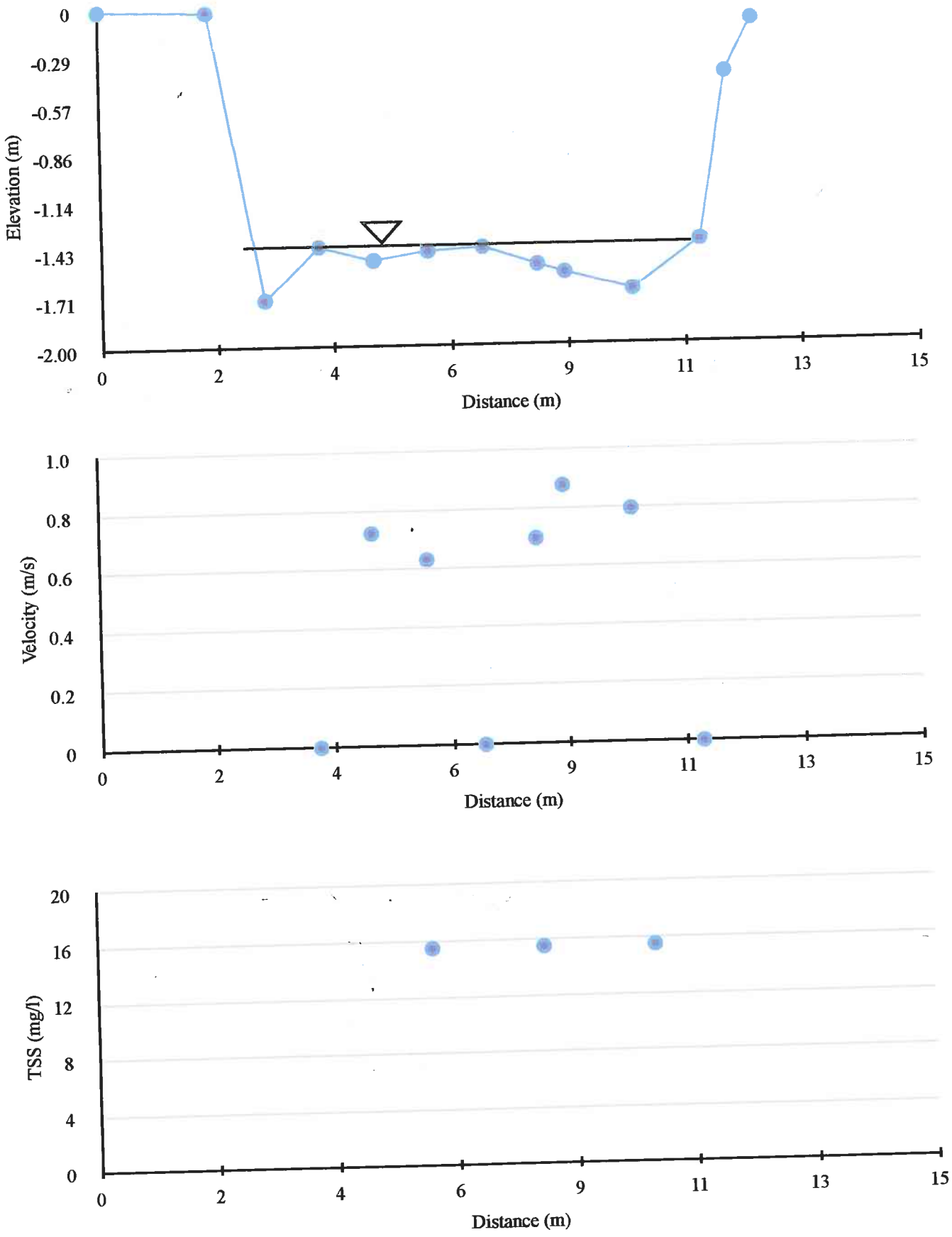

Figure 7. Graphs of the geomorphology (top), flow (middle),and suspended sediment (bottom) collected from upstream of Dam 3 of Baldwin Creek on March 14, 2011. Viewed looking upstream.

Table 9. Grain size calculations for Transect 3, upstream of Dam 3 pool, sample obtained on March 14, 2011.

					Sample ID	G65					
					Initial wt. (g)	289.939					
					% error	0.364					
m_ϕ	phi (ϕ)	Individual wt. (g)	Individual wt. %	% G S M	Cumulative wt. %	fm_ϕ	m_ϕ-x	$(m_\phi$-x$)^2$	$f(m_\phi$-x$)^2$	$(m_\phi$-x$)^3$	$f(m_\phi$-x$)^3$
-6.25	-6	0	0		0	0	-3.761	14.145	0.000	-53.199	0.000
-5.75	-5.5	0	0		0	0	-3.261	10.634	0.000	-34.677	0.000
-5.25	-5	56.103	19.4206651		19.4206651	-101.95849	-2.761	7.623	148.044	-21.047	-408.747
-4.75	-4.5	0	0		19.4206651	0	-2.261	5.112	0.000	-11.558	0.000
-4.25	-4	8.983	3.10956339		22.5302285	-13.215644	-1.761	3.101	9.643	-5.461	-16.981
-3.675	-3.35	8.747	3.02786941	81.243	25.5580979	-11.12742	-1.186	1.407	4.259	-1.668	-5.051
-3.175	-3	22.756	7.8772375		33.4353354	-25.010229	-0.686	0.471	3.707	-0.323	-2.543
-2.8	-2.6	21.044	7.28461003		40.7199454	-20.396908	-0.311	0.097	0.704	-0.030	-0.219
-2.3	-2	41.164	14.2493674		54.9693128	-32.773545	0.189	0.036	0.509	0.007	0.096
-1.75	-1.5	42.076	14.5650661		69.534379	-25.488866	0.739	0.546	7.955	0.404	5.879
-1.25	-1	33.823	11.7082002		81.2425792	-14.63525	1.239	1.535	17.974	1.902	22.270
-0.75	-0.5	29.163	10.0950904		91.3376696	-7.5713178	1.739	3.024	30.529	5.259	53.091
-0.25	0	14.31	4.95356251		96.2912321	-1.2383906	2.239	5.013	24.833	11.225	55.602
0.25	0.5	5.351	1.85230699		98.1435391	0.46307675	2.739	7.502	13.896	20.549	38.063
0.75	1	2.016	0.69786038		98.8413995	0.52339528	3.239	10.491	7.321	33.981	23.714
1.25	1.5	0.584	0.20215797		99.0435574	0.25269746	3.739	13.980	2.826	52.272	10.567
1.75	2	0.419	0.14504142	18.304	99.1885988	0.25382248	4.239	17.969	2.606	76.172	11.048
2.25	2.5	0.264	0.09138648		99.2799853	0.20561958	4.739	22.458	2.052	106.430	9.726
2.75	3	0.209	0.07234763		99.352333	0.19895598	5.239	27.447	1.986	143.797	10.403
3.25	3.5	0.225	0.0778862		99.4302192	0.25313016	5.739	32.936	2.565	189.022	14.722
3.75	4	0.335	0.1159639		99.5461831	0.43486463	6.239	38.925	4.514	242.856	28.163
4.25	> 4	1.311	0.45381694	0.454	100	1.92872201	6.739	45.414	20.610	306.048	138.890
	TOTAL	288.883				-248.902			306.535		-11.307
$mean_\phi$	-2.489										
$\sigma\phi$	1.751										
$SK\phi$	-0.113										
D50	-2.209	D84	-4.2127								

Table 10. Loss on ignition of sediment samples taken from Baldwin Creek on March 14, 2011.

	Wet sample wt. (g)	100C Sample (g)	Wet Bulk Density (g cm^-3)	Dry Bulk Density (g cm^-3)	Percent Water %
BC-11-1	9.930	7.488	1.8807	1.4182	24.6
BC-11-2	9.845	7.654	1.8646	1.4496	22.3
BC-11-3	9.279	6.924	1.7574	1.3114	25.4
BC-11-4	9.748	7.743	1.8462	1.4665	20.6
BC-11-5	9.434	6.922	1.7867	1.3110	26.6
BC-11-6	10.230	8.070	1.9375	1.5284	21.1
BC-11-7	9.433	6.939	1.7866	1.3142	26.4
BC-11-8	10.118	8.001	1.9163	1.5153	20.9
BC-11-9	9.462	7.690	1.7920	1.4564	18.7
BC-11-11	8.923	6.573	1.6900	1.2449	26.3
BC-11-12	9.256	7.116	1.7530	1.3477	23.1
BC2-11-8	10.390	8.389	1.9678	1.5888	19.3
BC2-11-G13	10.871	8.795	2.0589	1.6657	19.1
G14	10.425	8.184	1.9744	1.5500	21.5
G15	10.448	8.430	1.9788	1.5966	19.3
G23	10.445	8.412	1.9782	1.5932	19.5
G26	10.183	8.201	1.9286	1.5532	19.5
G28	10.600	8.648	2.0076	1.6379	18.4
G51	8.267	4.802	1.5657	0.9095	41.9
G53	10.682	8.801	2.0231	1.6669	17.6
G60	9.857	7.799	1.8669	1.4771	20.9
G62	10.325	8.383	1.9555	1.5877	18.8
G65	10.062	7.949	1.9057	1.5055	21.0
G78	9.348	6.490	1.7705	1.2292	30.6
Core 1 - 11.5 cm	2.017	2.017	2.017	2.017	16.5
Core 2 - 22.25cm	1.417	1.417	1.417	1.417	50.0
Core 2 - 27.50 cm	0.944	0.944	0.944	0.944	48.1
Core 2 - 34.25 cm	1.453	1.453	1.453	1.453	40.9
Core 2 - 38.00 cm	1.417	1.417	1.417	1.417	43.0
Core 2 - 43.00 cm	1.383	1.383	1.383	1.383	39.0
Core 2 - 53.50 cm	1.422	1.422	1.422	1.422	45.9
***Core 2 - 48.50 cm**	10.386	8.112	1.9670	1.5364	21.9

*Core 2 sample in plastic box not fully saturated.

4. Discussion

The flow velocity is greatest at transect 3, upstream of the pool, with an average flow of 0.7290 m/s and a maximum velocity of 0.8788 m/s near the middle of the channel, making Baldwin Creek most erosive there. Transects 1 and 2, in dam pool 1 and 3 respectively, have maximum velocities of 0.2337 m/s and 0.1575 m/s, which are much slower flows than at Transect 3. The greater flow velocity at Transect 3 is a result of the greater slope and smaller cross sectional area at that location. In summary, Baldwin Creek flow velocities are large enough to transport sand downstream but not to erode clay and gravel. Hence, the river is dominated by gravel and clay deposits.

The stream velocity will increase following the removal of the dams because the slope will increase and the cross sectional area in the pool will be reduced. Higher velocity will consequently increase the water's erosive capability and will possibly move larger sized sediment. The stream may adjust by downcutting into the sediment and or increasing bottom friction by establishing a rough bed.

To prevent the possible future erosion, engineering structures should be put into place. At dams 1 and 2, a cross vane could be built to allow fish passage and maintain the current water height. At dam 3 the velocity and erosive power are the greatest, so protecting against erosion here is crucial. The construction of rock vanes would promote fish passage, which is non-existent at the present, and would proactively stop erosion of the exposed banks.

The Hjustrom Diagram (Figure 8) illustrates the current day velocity versus grain size moved. Transect 1 has a velocity of 18.35 cm/s and a D84 of 16.82 mm. Transect 2 has a velocity of 10.49 cm/s and a D84 of 14.63 mm. Transect 3 has a velocity of 72.90 cm/s and a

D84 of 18.54 mm. The future projects are only for Transect 2 because it is the only transect near a fully intact dam, which will cause it to be greatly affected once the dam is removed. Based on the data, Transect 2 is projected to be similar to Transect 3 after the removal of the dam. This means that the channel at Transect 2 will have little area with the same amount of discharge, causing the velocity to increase (Q=VA). The area of Transect 3 is 0.075 m^2. By allowing the area of Transect 2 to become close to this with an area of 0.1 m^2 and the same discharge of 0.0495 m^3/s, the new velocity becomes 50 cm/s. As a result, once the dams are removed, Dam 3 pool will likely have downcutting, larger grain size on the bed, and the transport of sand and small gravel.

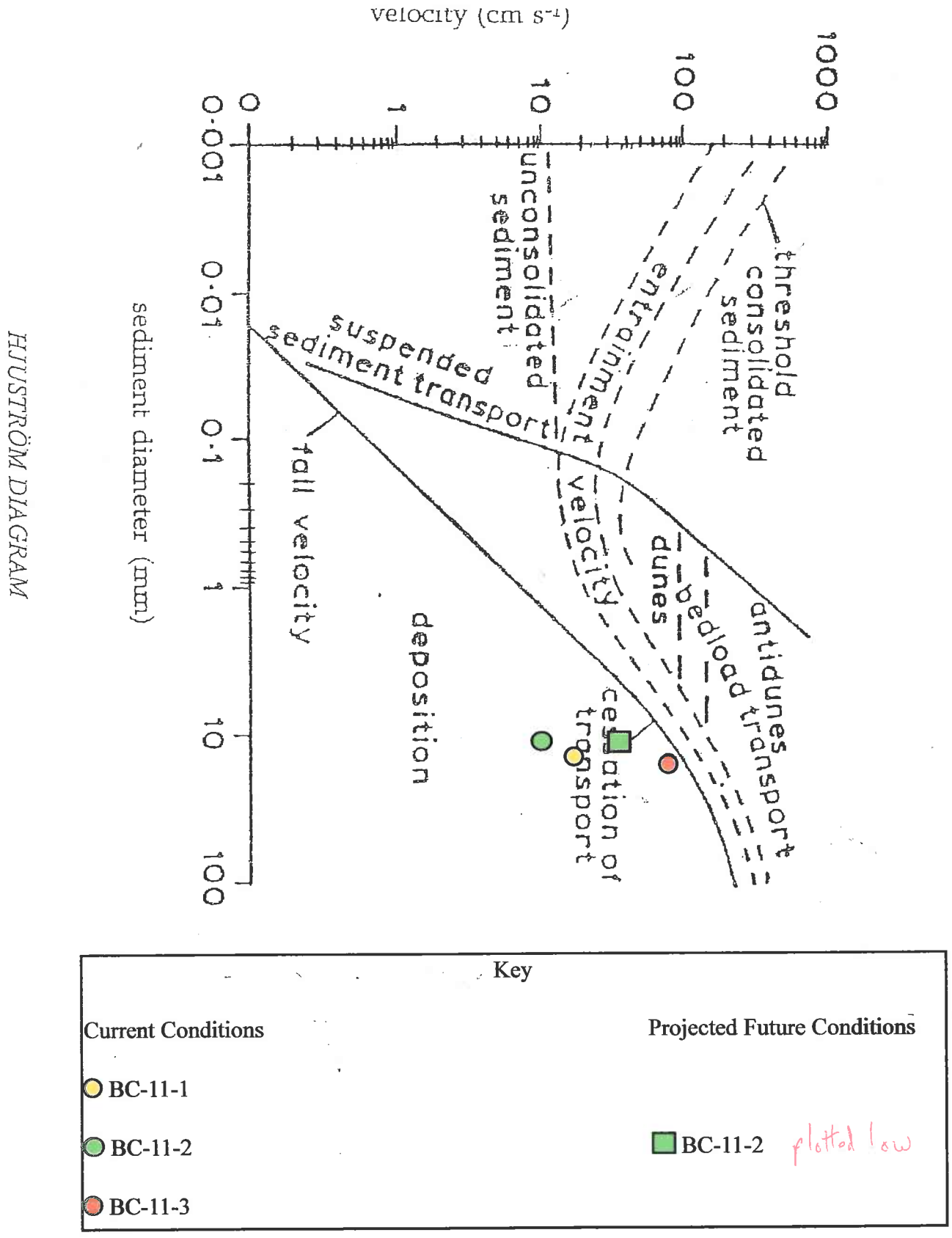

Figure 8. The hjustrom diagram. Transects 1, 2, and 3 are plotted, as well as the projected future conditions for Transect 2. These samples were obtained on March 14, 2011.

Acknowledgments

I would like to thank Dr. Peck and Max Gilliland for their help in the field and laboratory, as well as Tom Quick for suppling us with equipment. Also, Jerrod Bartley for the GIS, "Rocky River Watershed Program Project Profile". I would like to again thank Dr. Peck for his help on editing this paper.

References

Bartley, Jerrod. 2011. Rocky River Watershed Program. Cuyahoga Soil & Water Conservation District.