Spatial Variations in Sediment Characteristics in Baldwin Creek, Berea, Ohio

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Abstract

Removal of a dam will inevitably result in changes to river sediment characteristics. The goal of this study was to determine the relationship between dams and fluvial sediment type and thickness in lower Baldwin Creek in Berea, Ohio. To document the spatial variation in sediment, samples were taken from the riverbed and sediment thickness was measured from the confluence of Baldwin Creek and the East Branch of the Rocky River to a distance of 1050 meters upstream in Baldwin Creek. Samples were analyzed for grain size and magnetic properties. In addition, two sediment cores were collected from dam pools upstream of dams 1 and 3. Sediment is thickest upstream of the dams and the sediment with higher magnetic susceptibility was from the dam pools. Clay and gravel grain sizes dominated the riverbed sediment because Baldwin Creek flows are sufficient to transport sand-sized particles. A black mud having a bad odor was found both buried and on the riverbed upstream of Dam 3. Plotting several magnetic parameters reveals that Baldwin Creek sediments have magnetic contributions from both the lower shale bedrock and possibly fossil fuel combustion activities within the watershed.

Introduction

Baldwin Creek, a tributary of the Rocky River in Berea, Ohio (Figure 1), contains three dams near its confluence with the Rocky River that are being considered for removal. The reasons behind the removal of the dams are to attain higher Qualitative Habitat Evaluation Index (QHEI) scores, and to allow for the passage of fish, particularly the Bigmouth Shiner, which is especially affected by the dams (City of Berea). Baldwin Creek's channel is underlain mainly by shale and the creek has very little floodplain access. Dam 1 is located at Baldwin Creek's

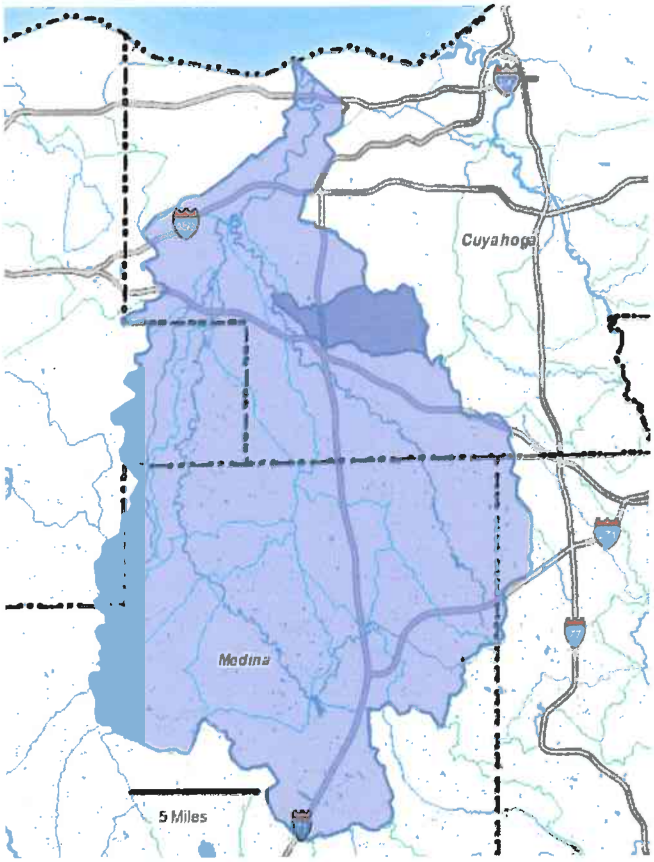


Figure 1. Baldwin Creek watershed (dark blue) in the Rocky River drainage basin (light blue) in Northern Ohio (City of Berea).

confluence with the Rocky River and is partially breached. Dam 2 is located 99.17 meters upstream of Dam 1 and is almost fully breached. Formerly, Baldwin Creek was used to fill a sandstone quarry but has since been diverted. The aforementioned quarry is now Coe Lake which lies northeast of Dam 3 (Figure 2). Dam 3 is 669.04 meters upstream of Dam 1.

The purpose of this study was to determine variations in sediment characteristics and thickness with respect to the three dams. This baseline information

Figure 2. Dam locations along Baldwin Creek (blue line) (City of Berea).

can be used to project changes to the sediment should the Baldwin Creek dams be removed.

Methods

Sediment samples were taken from the upper few centimeters of the riverbed. A scoop was scraped along the surface of the riverbed to obtain the sample (Figure 3). These samples were then separated into two parts; one part was used for grain size analysis and the other part was used to measure magnetic susceptibility at both high and low frequency. The subsample for grain size analysis was air dried, weighted, and separated by size using a Rotap shaker and a series of sieves. Weighting the grains in each sieve allowed the grain size distribution to be determined. Magnetic susceptibility is directly related to the magnetic content of the sample. Large susceptibility values indicate more magnetic material in the sample.

In order to measure sediment thickness, a steel probe rod was pushed into the sediment (Figure 3). When bedrock was reached or the probe could no longer be pushed deeper, the probe was removed and the section of the rod submerged in sediment was measured.

Two core samples were taken with a piston corer (Figure 3). Due to the difficulty of pushing the corer into the gravelly riverbed, the cores did not recover the entire deposit of loose sediment at their respective locations. We know the actual sediment thickness based on probe depths from locations close to the core sites.

Sediment sample and probe locations were logged on a GPS unit. Some of these locations plotted outside of the river channel due to GPS error. It is possible that the GPS unit lost satellite coverage within the steep sided river channel. The misplotted sites were dead-reckoned using field notes. Only one sample was taken outside of the channel.

Field data has the following coding. Sediment sample names begin with a G; probe depth measurement location names begin with a P; and locations where both probe measurements and sediment samples were obtained begin with G/P (Table 1). Core sample names begin with a C (Table 2).

Results

A total of 24 sediment samples and 75 thickness probes were measured for a distance of 1050 meters upstream of the Baldwin Creek confluence with the Rocky River (Table 1, Figures 4, 5, 6, & 7).

Mean grain size varies very little upstream of Dam 1 (Figure 8). All samples that were measured have mean grain sizes between granule and pebble based on phi (ϕ) values. There does not appear to be a close relationship between dam proximity and grain size for the samples measured. Sample 51, located at 912 meters upstream of Dam 3, was a black mud. However, field observation indicated that almost all of the study reach consisted of gravel-sized sediment on the channel floor.

As would be expected, water depth becomes greater immediately upstream of Dams 1 and 3 (Figure 8). At Dam 2, water depth increased immediately downstream in a deep scour pool on the river left side. Upstream of Dam 2, water depths are shallow (<50 cm) because the dam is breached. Dam 1 (which is partially breached) has a relatively shallow and short dam pool when compared with Dam 3, which is intact. The large variation in water depth upstream of Dam 3 reflects that samples were collected from both the center and sides of the channel.

Just as with water depth, sediment thickness appears to be related to dam proximity. Immediately upstream of Dams 1 and 3, there is an increase in sediment thickness (Figure 8). It should be noted that bedrock was only reached a few times with the probe rod. Some locations may have had more sediment that was simply too tightly packed to push the probe deeper. For example, the probe near 560 m revealed that there is over two meters of sediment present. This point is surrounded by thinner sediment thickness values that likely represent sediment too tightly packed to push the probe deeper. Upstream of Dam 3, fluvial sediment is generally between 50 and 100 cm thick. However, there are two locations where there was no sediment accumulated and the channel was floored by shale bedrock.

Two cores were collected from the dam pools and recovered interbedded gravel and clay with sharp contacts (Figures 9 and 10). Core 1, located in the Dam 1 pool, recovered 8.5 cm of gravel overlying brownish yellow clay (Figure 9). The only sand present is that which is mixed in with the gravel. Core 2 was collected in the Dam 3 pool and contained black mud buried beneath gravel (Figure 10). In core 2, with the exception of the black sediment at 42 cm, magnetic susceptibility generally decreases with depth (Figure 11).

Because both low and high frequency magnetic susceptibility were measured, the frequency dependence parameter (Xfd) was calculated. All sediment samples and a single shale bedrock sample that were tested for magnetic properties had frequency dependence (Xfd) values below 2% (Figure 12). Xfd values less than 2% indicate the absence of ultrafine magnetic grain sizes that are often found in soil A and B horizons. Larger susceptibility values (>50) are found upstream of the dams 1 and 3 (Figure 8). In a plot of Xfd versus X, the Baldwin Creek samples plot between typical sedimentary rocks and pollution (Figure 12). Based upon numerous samples, Dearing (1999) has constructed this plot to aid in identifying the magnetic signal results from fossil fuel combustion. It appears that Baldwin Creek samples have a contribution of shale bedrock and pollution magnetic components (Figure 12).

Discussion

Baldwin Creek sediment samples generally shared two striking characteristics: relatively high magnetic susceptibilities with frequency dependent susceptibilities below 2%, and a lack of sand sized particles.

These magnetic characteristics, as seen in Figure 12, suggest that the sediment contains particles from the combustion of fossil fuels (Dearing 1999). It is possible that vehicle pollution in runoff from roads in the watershed enters Baldwin Creek's sediment. Road runoff should be of concern as the stated goal of the dam removal is to improve the inhabitability of the river. The core data (Figure 11) shows increasing magnetic susceptibility with decreasing depth. Whether or not this trend indicates slowly increasing levels of runoff contamination through time is hard to say as the trend is weak. Regardless, it may be worth further investigation to confirm the presence of unique, highly magnetic combustion spherules by extracting them from the sediment with a powerful magnet. In addition, the few samples with large X values, black color, and strong odor (core 2, G/P 51) may be worth additional trace metal analyses.

The low amounts of sand-sized particles in the samples show that the velocity of the river is such that sand is always being transported. Sand is eroded at a lower velocity than either consolidated clay or gravel (Figure 13). Based upon the flow velocities measured in Baldwin Creek (LaValle 2011), the sand-sized sediment load is transported out of Baldwin Creek into the Rocky River. The interbedded gravels and clay in the cores represent periods with high flow velocity, such as during a flood, and periods of low velocity. During periods of high flow, gravel is transported and deposited and during periods of low flow, clay is deposited.

The variation in sediment thickness shows that the dams are causing sediment to be deposited as flow velocity decreases within the dam pools. Upstream of both Dams 1 and 3 there is about 1 m of fluvial sediment. Upon removal of the dams, it is possible that the river will erode some of this sediment. However, well upstream of the influence of Dam #2, there is about two meters of sediment (Figure 8). The stream bed consists of gravel and stream flow has not down cut into the underlying clay. With the planned addition of riffles (City of Berea), future erosion into the sediment will likely be minimal.

If the dams are removed, the resultant increase in flow velocity will likely mean less deposition of clay sized particles at the locations of the former dam pools. The gravel and pebble sized particles that have characterized periods of higher flow in Baldwin Creek will likely become the dominant grain size present.

Conclusion

The study found magnetic evidence of possible fossil fuel pollution in Baldwin Creek sediment. In addition, sediment thickness increased on the upstream sides of dams 1 and 3. In areas of Baldwin Creek that are already outside of dam influence (between Dams 2 and 3), gravelly sediment was found above clay. In places, this clay was over two meters thick. Following potential dam removal in the future, stream erosion may cut into the dam pool sediment. However, both armoring of the bed by gravel and the planned addition of vanes may minimize this erosion.

Figure 3. A.) Pushing the probe into the sediment. B.) Measuring sediment depth with a 1.5 m stick by subtracting water depth from total probe depth. C.) The piston core used to obtain samples. D.) The full scoop after being scraped along the riverbed.

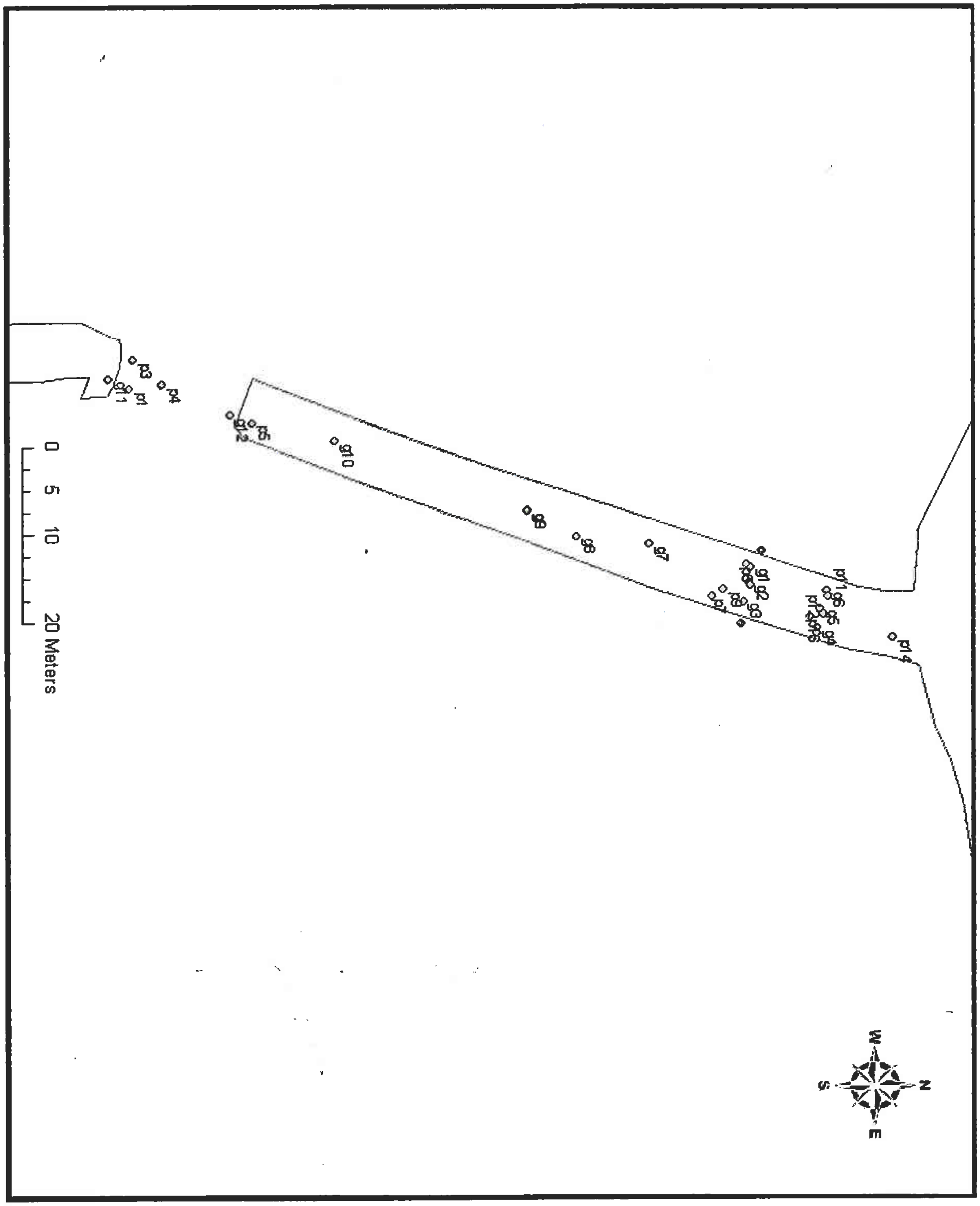


Figure 4. Sediment sample and probe locations in Baldwin Creek.

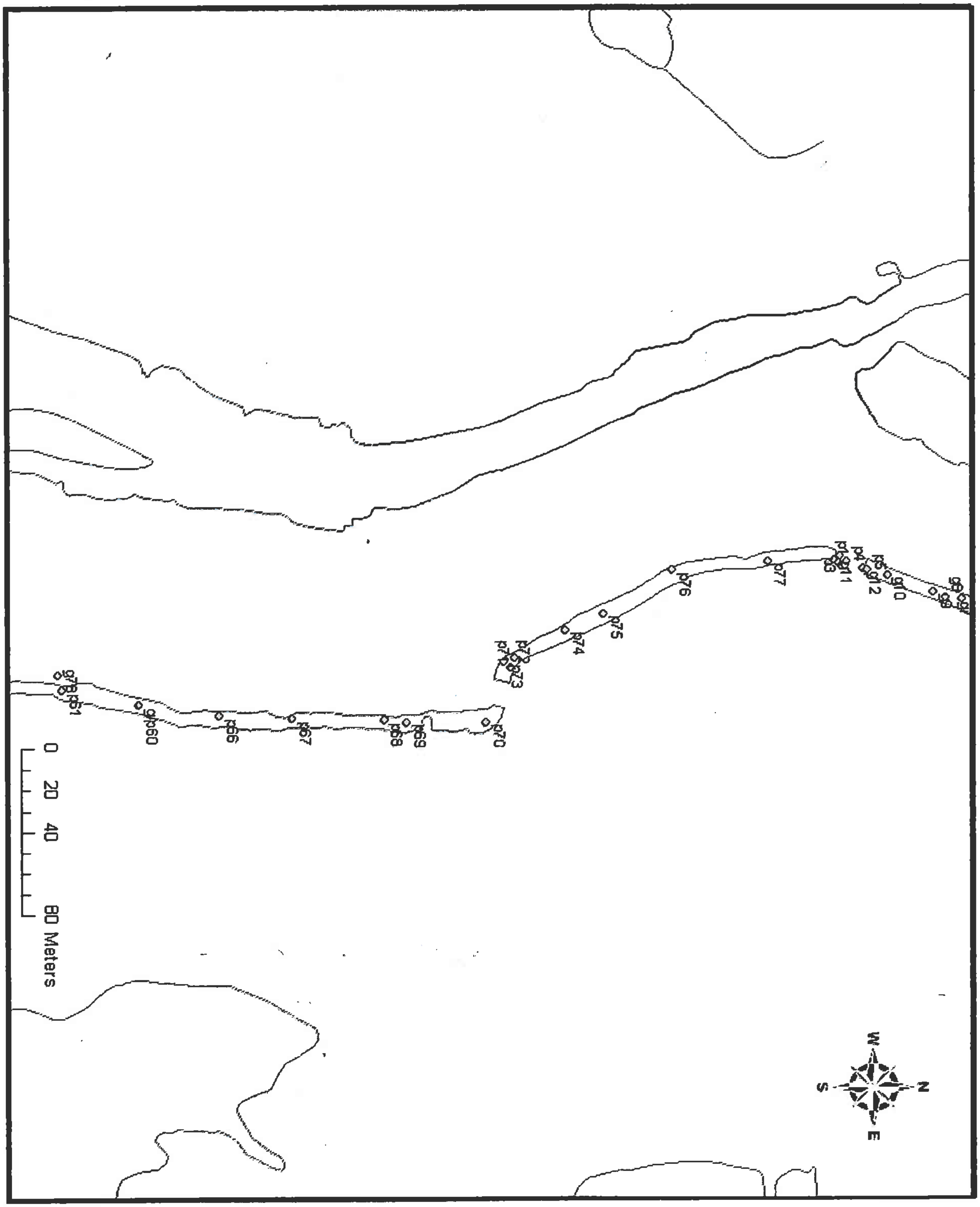


Figure 5. Sediment sample and probe locations in Baldwin Creek.

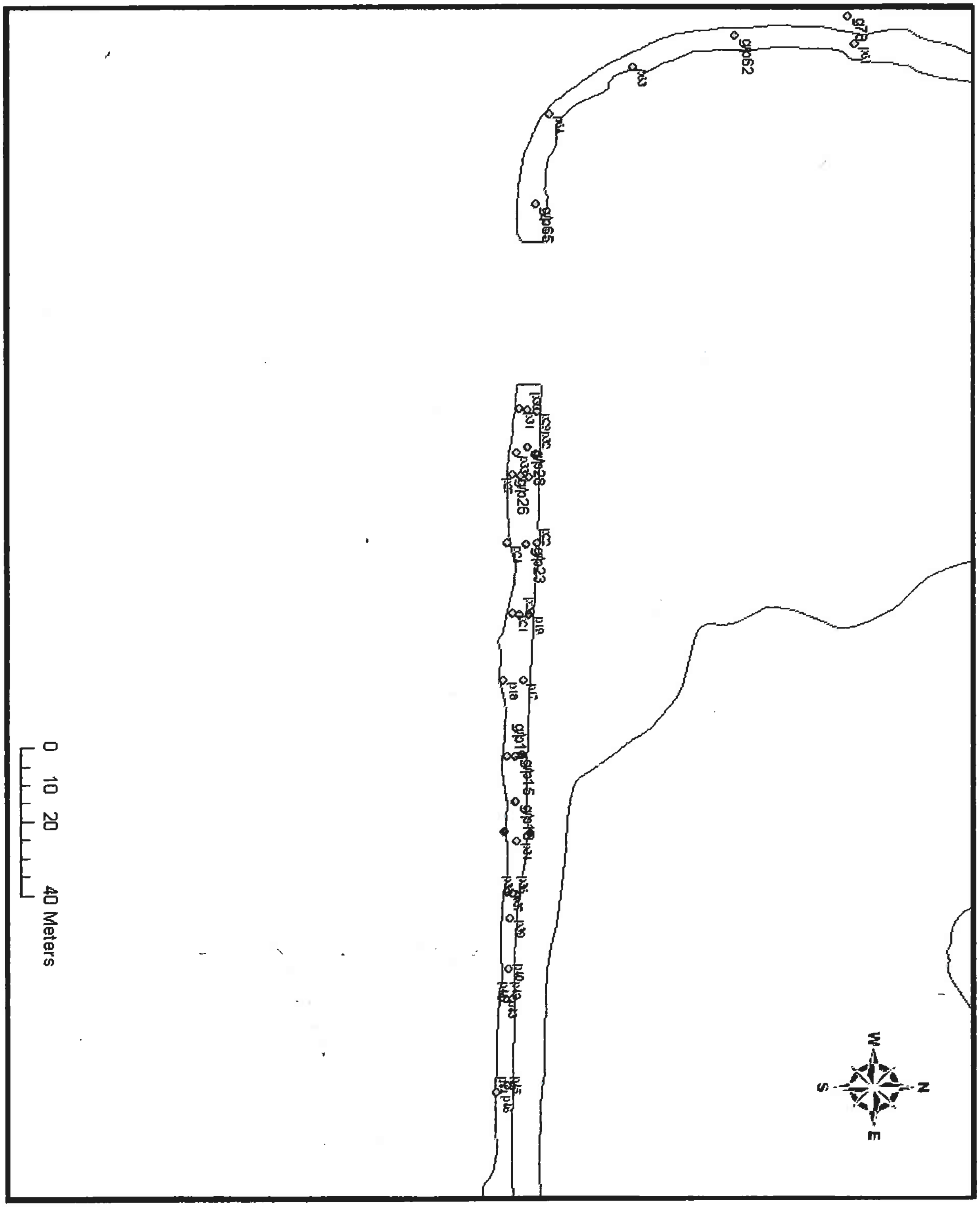


Figure 6. Sediment sample and probe locations in Baldwin Creek.

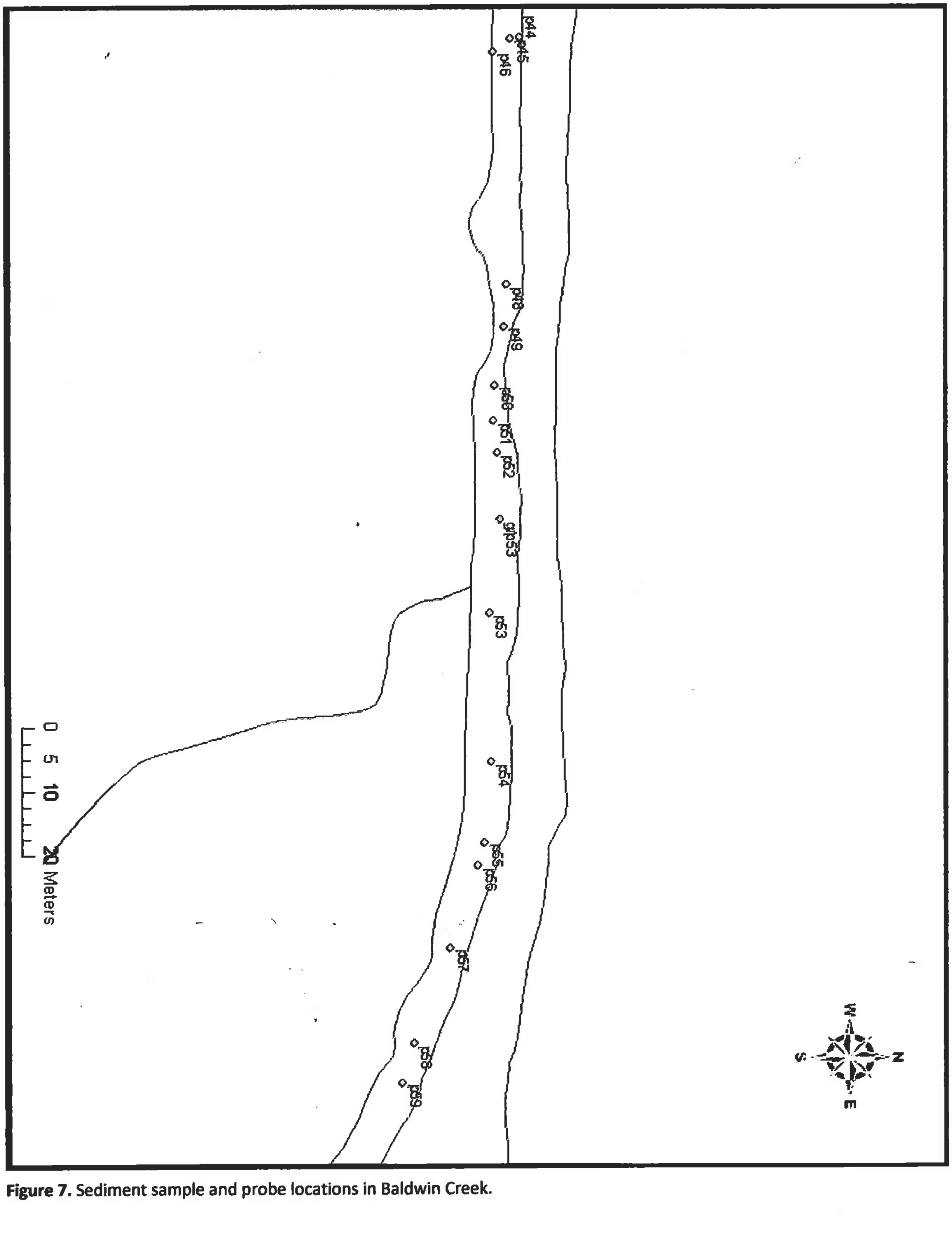


Figure 7. Sediment sample and probe locations in Baldwin Creek.

Table 1. Sediment sample and probe locations from Baldwin Creek collected in February and March 2011.

Sample	Distance From Dam 1	Dead Reckoning	Probe Depth	Water Depth	Sediment Thickness	Xlf	Xhf	XFd	Grain Size
-	(m)	-	(cm)	(cm)	(cm)	$(10^{-6}m^3kg^{-1})$	$(10^{-6}m^3kg^{-1})$	(%)	(Mean ϕ)
P1	94.89	yes	38	0	38	-	-	-	-
P2	94.89	-	84	84	0	-	-	-	-
P3	94.89	yes	54	54	0	-	-	-	-
P4	91.08	-	95	0	95	-	-	-	-
P5	80.23	yes	12	0	12	-	-	-	-
P6	19.62	yes	112	52	60	-	-	-	-
P7	23.36	yes	96	51	45	-	-	-	-
P8	22.81	-	168	47	121	-	-	-	-
P9	22.41	-	78	31	47	-	-	-	-
P10	19.62	-	138	49	89	-	-	-	-
P11	11.42	yes	112	44	68	-	-	-	-
P12	11.42	yes	130	57	73	-	-	-	-
P13	11.42	-	128	53	75	-	-	-	-
P14	2.51	yes	142	64	78	-	-	-	-
P16	12.61	-	130	58	72	-	-	-	-
G1	19.62	yes	-	-	-	93.6	92.8	0.9	-2.382
G2	19.62	yes	-	-	-	77.2	76.9	0.4	-2.985
G3	19.62	yes	-	-	-	79.4	78.8	0.8	-1.664
G4	10.51	yes	-	-	-	86.6	86.2	0.5	-
G5	10.51	yes	-	-	-	112.8	111.8	0.9	-
G6	10.51	yes	-	-	-	48.1	48	0.2	-
G7	31.86	-	-	-	-	28.5	28	1.8	-
G8	40.6	-	-	-	-	94.9	94.8	0.1	-
G9	46.87	-	-	-	-	71.6	71.1	0.7	-
G10	69.69	-	-	-	-			-	-
G11	97.56	yes	-	-	-	28.9	28.8	0.3	-
G/P13	774.71	-	100	0	100	124.3	122.5	1.4	-1.997
G/P14	762.55	yes	119	83	36	30.3	30	0.9	-
G/P15	762.55	yes	131	100	31	47.7	47.5	0.4	-2.91
P16	762.55	yes	122	104	18	-	-	-	-
P17	742.17	yes	122	84	38	-	-	-	-
P18	743.17	yes	138	26	112	-	-	-	-
P19	724.11	-	90	22	68	-	-	-	-
P20	724.11	yes	123	56	67	-	-	-	-
P21	724.11	yes	132	69	63	-	-	-	-
P22	705.22	yes	104	57	47	-	-	-	-
G/P23	705.22	yes	129	54	75	39.6	39.3	0.8	-
P24	705.22	-	134	68	66	-	-	-	-
P25	687.08	-	110	64	46	-	-	-	-
G/P26	687.08	yes	152	65	87	43.3	42.8	1.2	-
P27	687.08	yes	145	79	66	-	-	-	-
G/P28	678.86	yes	146	77	69	43.4	43	0.9	-1.392
P29	669.04	yes	154	105	49	-	-	-	-
P30	669.04	yes	115	95	20	-	-	-	-
P31	669.04	yes	158	121	37	-	-	-	-
P32	680.88	yes	135	58	77	-	-	-	-
P33	680.88	yes	100	83	17	-	-	-	-
P34	785.7	yes	101	65	36	-	-	-	-
P35	799.96	yes	98	46	52	-	-	-	-
P36	799.96	yes	92	55	37	-	-	-	-
P37	799.96	yes	73	42	31	-	-	-	-
P38	806.28	-	88	88	0	-	-	-	-
P39	806.28	yes	68	32	36	-	-	-	-
P40	820.25	yes	48	48	0	-	-	-	-
P41	828.35	yes	98	98	0	-	-	-	-
P42	828.35	-	64	62	2	-	-	-	-
P43	828.35	yes	31	31	0	-	-	-	-
P44	851.84	yes	64	64	0	-	-	-	-
P45	851.84	-	78	71	7	-	-	-	-
P46	853.87	-	75	75	0	-	-	-	-
P47	874.35	-	98	50	48	-	-	-	-
P48	890.47	yes	110	22	88	-	-	-	-
P49	896.97	yes	92	0	92	-	-	-	-

Table 1. Sediment sample and probe locations from Baldwin Creek collected in February and March 2011.

Sample	Distance From Dam 1	Dead Reckoning	Probe Depth	Water Depth	Sediment Thickness	Xlf	Xhf	XFd	Grain Size
-	(m)	-	(cm)	(cm)	(cm)	$(10^{-6}m^3kg^{-1})$	$(10^{-6}m^3kg^{-1})$	(%)	(Mean ϕ)
G/P51	912.08	yes	128	70	58	63	62.8	0.3	-
P52	916.89	yes	124	18	106	-	-	-	-
G/P53	942.06	-	154	100	54	22.4	22.1	1.3	-1.274
P54	965.33	yes	79	40	39	-	-	-	-
P55	978.17	yes	104	62	42	-	-	-	-
P56	981.74	yes	61	61	0	-	-	-	-
P57	995.44	yes	68	68	0	-	-	-	-
P58	1011.23	yes	92	51	41	-	-	-	-
P59	1017.78	yes	90	90	0	-	-	-	-
G/P60	463.79	-	49	33	16	42.4	42.3	0.2	-1.856
P61	501.78	-	79	50	29	-	-	-	-
G/P62	533.75	-	82	62	20	25	24.9	0.4	-
P63	562.42	-	258	51	207	-	-	-	-
P64	589.42	-	70	46	24	-	-	-	-
G/P65	613.12	-	98	65	33	17.3	17.1	1.2	-2.489
P66	423.76	-	50	45	5	-	-	-	-
P67	388.55	-	41	24	17	-	-	-	-
P68	344.81	yes	39	26	13	-	-	-	-
P69	334.09	-	46	31	15	-	-	-	-
P70	295.65	-	154	60	94	-	-	-	-
P71	262.89	-	40	40	0	-	-	-	-
P72	267.04	yes	29	29	0	-	-	-	-
P73	267.04	-	99	17	82	-	-	-	-
P74	234.79	-	82	38	44	-	-	-	-
P75	214.52	yes	91	23	68	-	-	-	-
P76	175.93	-	53	20	33	-	-	-	-
P77	129.86	-	42	30	12	-	-	-	-
G78	503.68	-	-	-	-	32.9	32.5	1.2	-
G79	783.35	-	-	-	-	226.5	224.2	1	-
Dam 1	0	-	-	-	-	-	-	-	-
Dam 2	99.17	-	-	-	-	-	-	-	-
Dam 3	669.04	-	-	-	-	-	-	-	-
Transect 1	19.61	-	-	-	-	-	-	-	-
Transect 2	783.35	-	-	-	-	-	-	-	-
Transect 3	906.43	-	-	-	-	-	-	-	-
Core 1	20.62	-	-	-	-	-	-	-	-
Core 2	699.68	-	-	-	-	-	-	-	-

Table 2. Core samples and depths taken February and March 2011.

Core Sample Name	Core Depth	Xlf	Xhf	Xfd
-	(cm)	$(10^{-6}m^3kg^{-1})$	$(10^{-6}m^3kg^{-1})$	(%)
C1 11-13cm	11	33.6	33.2	1.2
C2 21-24cm	21	37.8	37.1	1.9
C2 27-29cm	27	29.5	28.9	2
C2 31-39cm	31	32.2	31.9	0.9
C2 32.5-35.5cm	32.5	25.7	25.2	1.9
C2 42-44cm	42	78.9	77.4	1.9
C2 47-49cm	47	14.1	13.4	4.9
C2 52-54cm	52	22.1	21.9	0.9

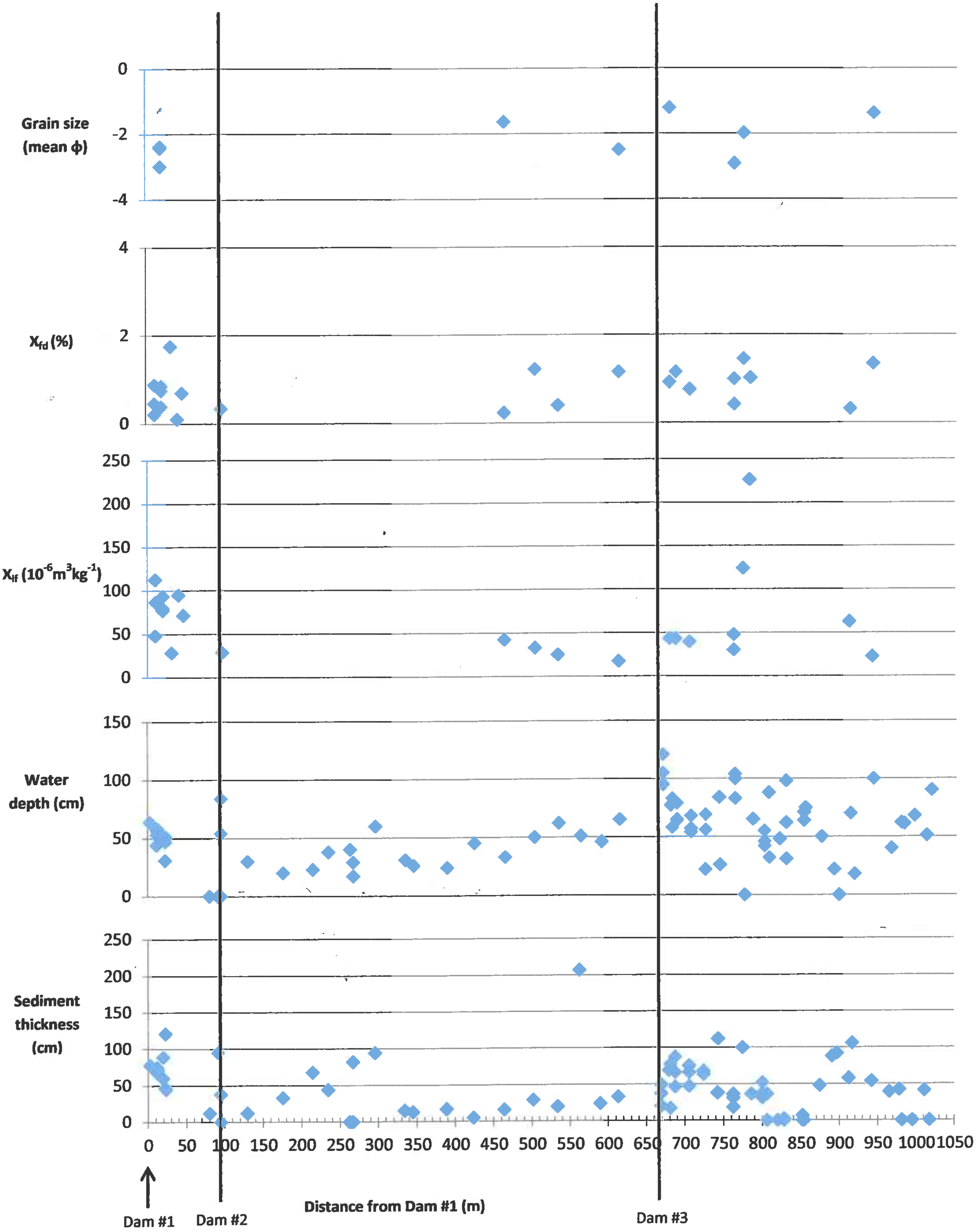
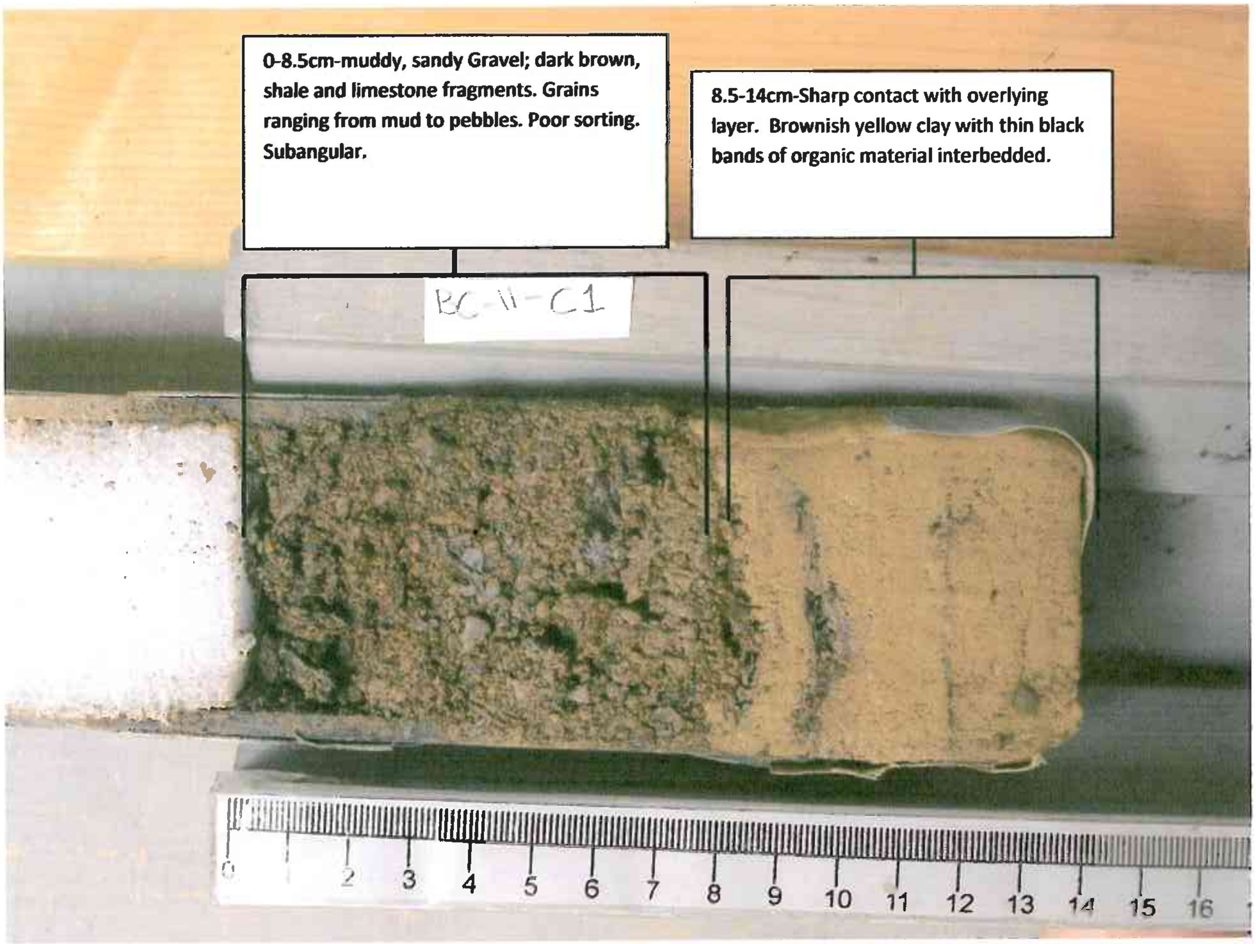


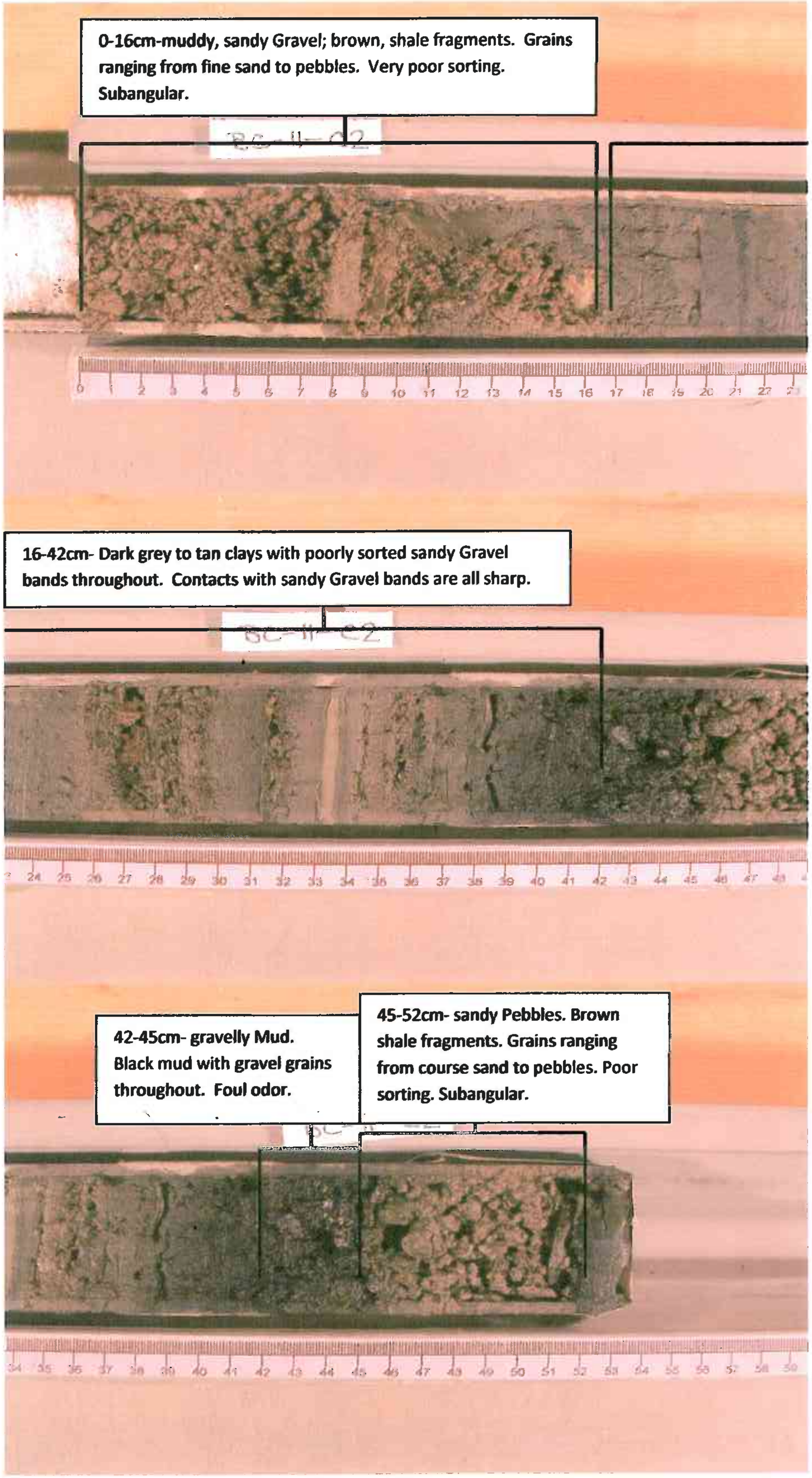
Figure 8. Variation in sediment thickness, water depth, Xlf, Xfd, and grain size upstream of Dam 1. Baldwin Creek.



0-8.5cm-muddy, sandy Gravel; dark brown, shale and limestone fragments. Grains ranging from mud to pebbles. Poor sorting. Subangular.

8.5-14cm-Sharp contact with overlying layer. Brownish yellow clay with thin black bands of organic material interbedded.

Figure 9. Photograph of core 1 and lithological description (scale in cm). Core 1 was obtained within the Dam 1 dam pool, 20.62m upstream.



0-16cm-muddy, sandy Gravel; brown, shale fragments. Grains ranging from fine sand to pebbles. Very poor sorting. Subangular.

16-42cm- Dark grey to tan clays with poorly sorted sandy Gravel bands throughout. Contacts with sandy Gravel bands are all sharp.

42-45cm- gravelly Mud. Black mud with gravel grains throughout. Foul odor.

45-52cm- sandy Pebbles. Brown shale fragments. Grains ranging from course sand to pebbles. Poor sorting. Subangular.

Figure 10. Photographs of core 2 and lithological description (scale in cm). Core 2 was obtained within the Dam 3 dam pool, 37.67m upstream.

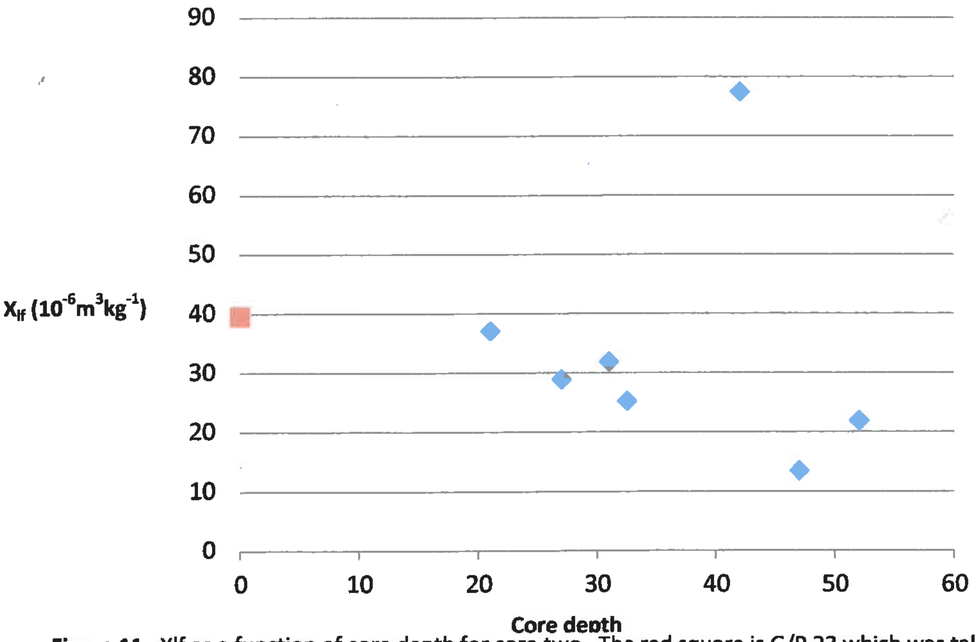


Figure 11. Xlf as a function of core depth for core two. The red square is G/P 23 which was taken from the riverbed at the location of core 2. The sample with the Xlf value near 80 is the black sediment starting at 42 cm.

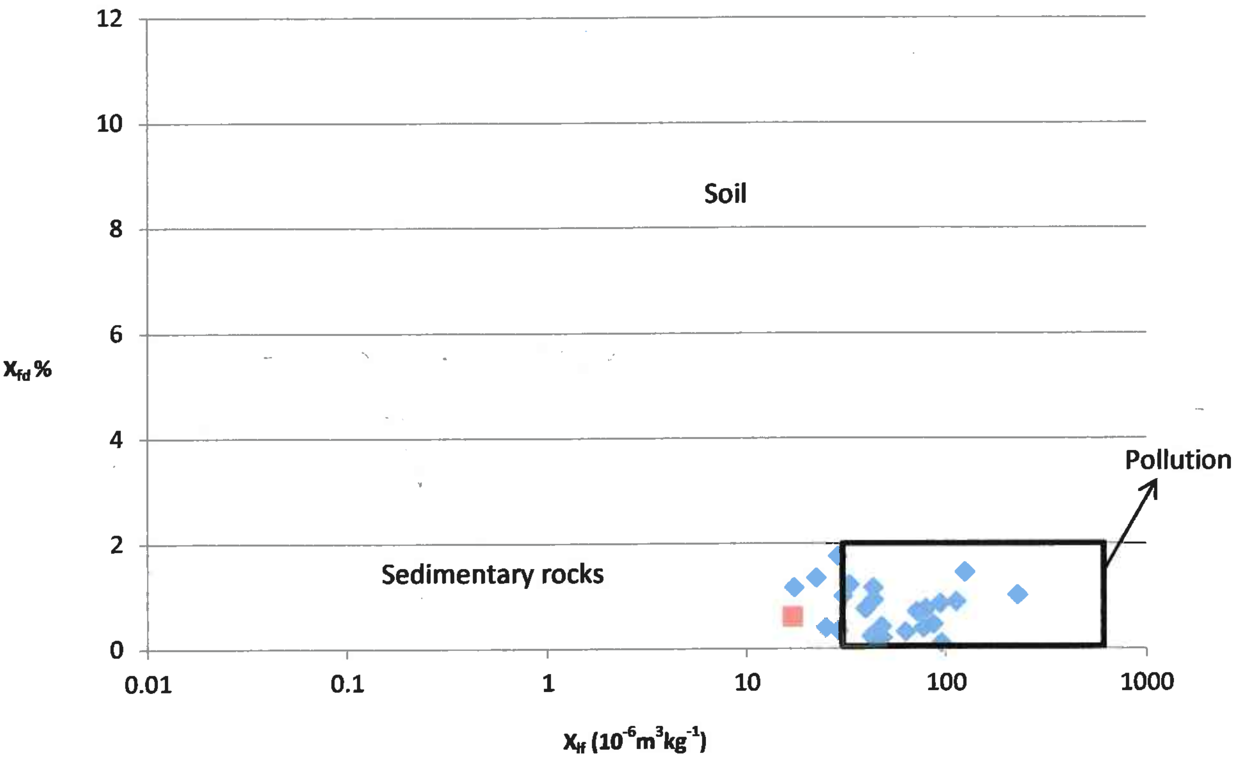


Figure 12. Scatter plot of Xlf versus Xfd for sediment samples and shale bedrock (red square). (after Dearing, 1999).

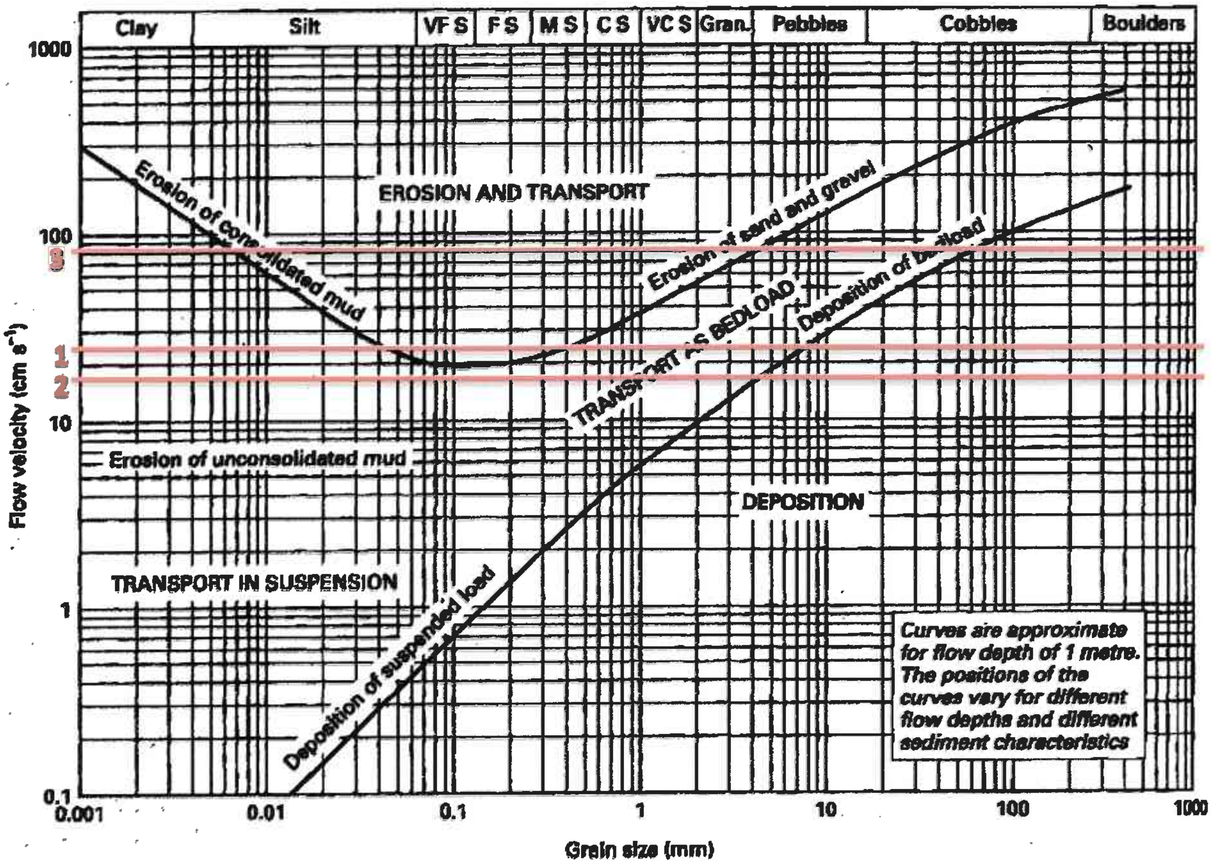


Figure 13. Hjulstrom diagram showing the relationship between grain size and flow velocity (theartofdredging.com). The maximum velocity measured at transects 1, 2, and 3 are superimposed.

Acknowledgements

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