The investigation of channel-reach morphology in two mountain drainage basins, Ogontz Lake and Sandy Pond, NH

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Abstract

The classification of two mountain drainage basins into specific channel-reach types using guidelines in Montgomery and Buffington (1997) is useful when attempting to assess channel condition and response potential. Field investigations of two streams located at Ogontz Lake and Sandy Pond in New Hampshire (figure 1) were synthesized in order to demonstrate characteristic reach type. The stream at Sandy Pond had a downstream progression of reach type: step pool, to transitional, to plane bed. The change in gradient and width/depth ratio corresponds with changing reach type. The average gradient along each reach decreases from 0.1403, 0.0293 to 0.0175 m/m. Width/depth ratios were clearly affected by channel morphology and disturbances from woody debris, road, dams, and bedrock. The channel responds to disturbances by altering the streams width and/or depth, thus causing a fluctuation in the W/D ratio. At Ogontz Lake the section of stream surveyed only displayed one reach type, step pool. The gradient along this reach was ~ 0.10 m/m and had a total elevation change of 110 meters. The characteristic stair step bedform of a step pool reach has the greatest change in elevation and change in W/D ratio. At Ogontz Lake, the step pools decrease in size as does the W/D ratio, ~ 70 along the upper reach decreases to ~20 along the lower reach. Based on channel type both streams are predominantly supply limited mountain drainage basins and thus have a high transport capacity. The plane bed channel type at Sandy Pond is a zone of transition from supply limited to transport limited. The association of reach type, to trending transport limited and sediment limited reaches combined with the identification of external influences provides a conceptual framework within which to investigate channel processes, assess channel conditions, and responses to watershed disturbances.

INTRODUCTION

The morphology of mountain stream channels is greatly affected by influences of the greater drainage basin. The ability to classify streams and then relate the morphology to processes in mountain channels can aid in predicting their response to natural and human disturbances. The classification schemes of channel-reach morphology presented by Montgomery and Buffington (1997) attempts to organize channel processes in order to assess channel condition, response potential, and relations to ecological processes. The field studies and thus conclusions were based on mountain streams in the Pacific Northwest with large drainage areas, between 8 and 129 km² and high relief, up to1985 m are much larger drainage basins compared with the streams of this study (table 1). In this study, the main variables studied were gradient, change in elevation, W/D ratio coupled with field observations comprise only a fraction of the parameters discussed in Montgomery and Buffington (1997).

METHODS

Field surveys were conducted on streams in two mountain drainage basins in New Hampshire: Ogontz Lake and Sandy Pond (table 1), the streams were unnamed but will be referred to as Ogontz stream and Sandy stream in this paper. In each survey area, channel reaches were classified using channel-reach classification described by Montgomery and Buffington (1997). The seven reach types are colluvial, bedrock, and five alluvial channel types (cascade, step pool, plane bed, pool riffle and dune ripple). The surface water slope, bottom gradient, and distance were determined using an auto-level and stadia rod.

RESULTS

Sandy Pond

At Sandy stream two Montgomery and Buffington reach morphologies were identified, step pool and plane bed. There is a reach, ~118 m long separating the two reach types that I've called "transitional", as it displays characteristics of both step pool and plane bed, although this reach type is not defined by Montgomery and Buffington. The first reach type, plane bed extends from the delta to ~242 m upstream. The substrate is predominantly gravel sized grains but becomes progressively coarser from silty clays at the delta to some large cobble clasts upstream. This reach has small meanders, lacks discrete bars, is unconfined by valley walls and all clasts are below the water line. The width/depth (W/D) ratio has little variability, ranging from 2.3 to 18, but most ratios are ~4 (figure 2). Woody debris has increased the width of the channel, forcing the water to bankfull and thus causing a W/D ratio of 18. The average gradient of the streambed was 0.0175 m/m, the smallest of all Sandy stream reach gradients (figure 3).

The transitional stretch has gravel to small boulder sized clasts that break the water surface. The channel straightens as the meanders become less frequent and gradient increases to 0.0293 m/m (average gradient for this reach). The W/D ratio increases by approximately five times and has more fluctuations than the ratio of the plane bed reach (figure 2).

A paved road divides the transitional reach at ~330 m from the delta. There is a pipe with a diameter of ~1.5 m that connects the stream under the road. This has caused the stream to pool water immediately above and below the pipe. The transitional reach continues for 30 meters upstream of the road.

The final reach, step pool, has longitudinal steps formed by large clasts organized into discrete accumulations that span the channel width (figure 4). Each step is separated by a pool containing smaller sized clasts that are cobble to small boulder size. There is a terrace located along the steep valley walls of this reach. Granitic bedrock is exposed at numerous locations along this reach, the precise location of only one is known and is labeled on figure . The gradient of the stream steepens substantially along this reach (figure 5). The W/D ratios have the greatest fluctuations along this reach, the values range from 5 to 180 (figure 2). The large peaks on figure 2 correspond with the steps on figure 4 as do the troughs with the pools. The water depth decreases along a step, thus increasing the width to depth ratio, when the water depth increases as in a pool the W/D ratio will decrease. Stream widening is most evident along the last 75 m of stream surveyed. A large dam built of boulders and logs is causing the water width to increase immediately downstream. The average gradient below the dam at Sandy stream is also greater, 0.1403 m/m compared with the remaining step pool reach that has a gradient of 0.1159 m/m (figure 3).

Ogontz Lake

Two stretches of Ogontz stream were surveyed and both were categorized as having a step pool reach morphology. At approximately 1 km from the delta we began surveying and worked downstream, there is a gap in the data of unknown distance, but is approximately 1 kilometer from the delta. Ogontz stream is an ephemeral mountain stream, ~ 2 km long with a steep gradient and no tributaries. The stream was dry from the delta to ~ 0.2 km upstream and had gravel to cobble sized grains filling the channel. The bed was relatively straight and did not have noticeable changes in elevation. The stream parallels Stickney Road for the first 1.3 km and has at least three driveways have been built across it. Ogontz stream is confined by steep valley walls and has a larger flood plain than Sandy stream but did not have noticeable terrace formations. The floodplain has large amounts of moss covered woody debris and is vegetated.

The stream morphology is strongly controlled by large boulders to cobble sized clasts. The steps were formed from large boulder sized clasts while smaller sized grains (gravel to cobble sized) collected in the pools. There were few areas that bedrock (mica schist) was exposed, although it was very weathered and usually was covered by clasts. The stair-step shape of the bed is reflected beautifully in the plot of change in elevation vs. distance (figure 6). In the upper reach the steps have a greater change in elevation and extend for longer distances than steps in the lower reach. Along the lower reach the steps and pools are fairly equidistant.

The W/D ratios for Ogontz stream plot in a similar fashion to those of the step pool reach at Sandy stream. The W/D ratio along a step is generally greater than at a pool (figure 7). There was less variability in the width and depth measurements at Ogontz stream and thus the W/D ratio is less than 70, however at Sandy stream the maximum W/D ratio is 180 (figure 2). The W/D ratio is less variable along the lower reach than the upper reach, as the sequence of step pool has a smaller change in elevation (figures 6 and 7). Ogontz stream has a greater overall change in elevation (~ 60 m) than at Sandy stream that had a total change of 30 m (figure 5 and 8). The upper and lower reach gradients are 0.099 m/m and 0.013 m/m respectively and have a linear trend (figure 8).

DISCUSSION

There is a general downstream progression of reach types at Sandy stream that proceeds as plane bed, transitional, plane bed (figure 4). I suspect that Ogontz stream when follows the same progression when at full flow because of the bedform material and shape of the dry reach upstream of the delta. The upper reaches that were not surveyed at both locations could have regressed to other reach slopes (cascade and bedrock) described by Montgomery and Buffington. Especially at Sandy stream that had many tributaries and a larger drainage area. At Finney Creek watershed, Washington the reach slope decreased with drainage area causing a diversification in reach type with increased drainage area (Montgomery and Buffington, 1997).

The W/D ratios are greatly influenced by erosional resistance of the channel banks. On figure 2 and figure 7 the peaks are due to some channel disturbance that has diverted or changed the water flow and/or channel morphology, i.e. woody debris, dams, bedrock (lithology) and drainage pipes. Exposures of granite at Sandy stream caused upstream scouring of the channel bank, increasing the W/D ratio and gradient (figure 5). While at Ogontz stream the bedrock lithology was a biotite schist that had been weathered to regolith along the cut banks but was exposed along the channel bed. This rock is much less resistant to erosional processes than the granite at Sandy stream and thus has a smaller effect on the stream reach morphology, particularly gradient.

With the reach type classifications for both Sandy stream and Ogontz stream the sediment supply and transport capacity of the streams can be inferred using the results from Montgomery and Buffington (1997). The typical downstream sequence of Montgomery and Buffington channel morphologies is accompanied by trends of sediment supply and transport capacity.

Large bed-forming material (step-pool) generally is mobile only during relatively infrequent hydrologic events. Significant movement of all grain sizes occurs during extreme floods. During more frequent discharges, finer material stored in pools travels as bedload over stable bed-forming clasts. The transport of all the pool-filling material indicates that sediment transport of non-step forming grains is supply limited. Warburton (1992) suggests three phases of sediment transport in step-pool channels: a low flow flushing of fine-grained material; frequent high-flow mobilization of pool-filling gravels; and less-frequent higher discharge mobilization of step-forming grains. Plane bed channels are suggested to be transitional between supply- and transport- limited morphologies (figure 9). Transport capacity generally decreases downstream due to the slope decreasing faster than the depth increases and thus becomes transport limited in downstream reaches. The above information suggests that Sandy stream (within the surveyed section) progresses from supply limited in the step pool reach to a transitional (supply limited to transport limited) in the plane bed reach. The sediment carried down Sandy stream in storm events will likely end up in the plane bed reach and neighboring delta.

The relative trends in sediment supply and transport capacity are very important when looking at the stream's adjacent delta to record paleoclimate. Insignificant sediment storage, as in supply limited reaches indicates that virtually all of the material delivered to the channel is transported downstream (Montgomery and Buffington 1997). During storm events the fine grained materials stored will be become mobile and be transported to the delta.

SUMMARY

This classification scheme can serve as a powerful tool to illustrate process linkages within mountain drainage basins. Although, it may not be ideal in all purposes and mountain regions it could be useful for integrating the diverse and range of disciplines that attempt to understand stream processes. In the areas of study there were two main Montgomery and Buffington channel reach morphologies step pool and plane bed. Sandy stream had both morphologies that were adjoined by a reach of transitional morphology that displays characteristics of both, whereas Ogontz stream has only step pool. The step pool reaches have steep gradients, greater than 0.1 and large fluctuations in the W/D ratio, over 170. The lone plane bed reach extends from the delta at Sandy stream, has a relatively steady W/D ratio, ~4, a gradient less steep than the step pool reaches and has and average gradient of 0.0175 m/m. The response of the stream to both natural and anthropogenic disturbances is prevalent at both streams, increasing W/D ratios and steepening gradient. The predominance of step pool morphologies reflects the dominance of transport capacity. Thus allowing virtually all of the material delivered to the channel from upstream reaches to be transported downstream, and into the delta. The

potential stream response when there is watershed disturbances depends on the reach type.

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FIGURES

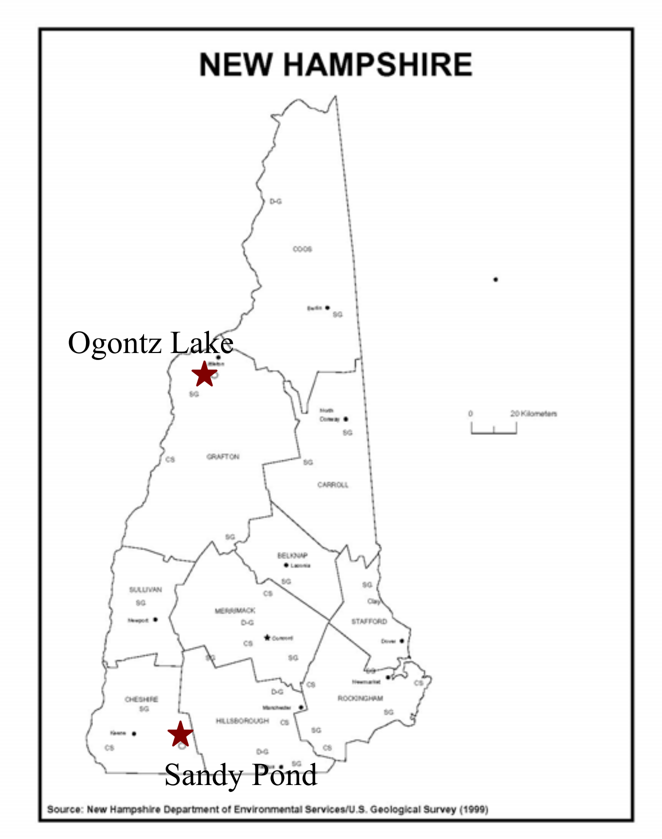


Figure 1. Location map of two stream locations. Both areas have glacial till and eratics with mountainous terrain. Source: USGS (1999)

Study Area	Geology	Drainage Area (km²)	Change in Relief (m)
Ogontz Lake, NH	Chlorite schist, quartzite, glacial till	1.2	460
Sandy Pond, NH	Granodiortie, granite, boulder eratics	1.0	95

Table 1. Study Area Characteristics

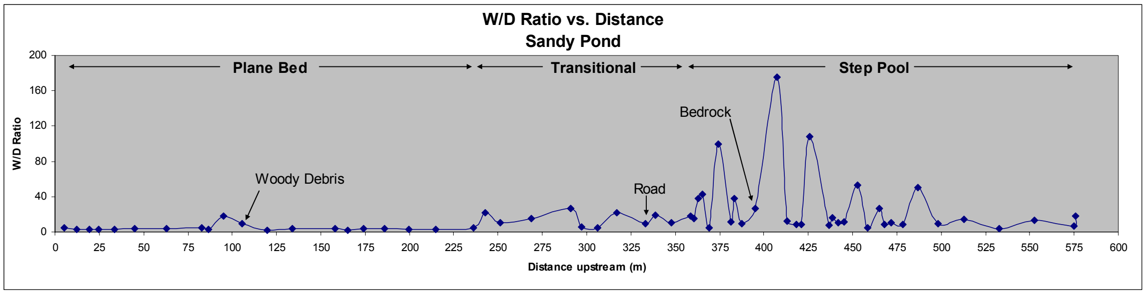


Figure 2. There is an upstream progression of stream type morphology from plane bed, a transitional reach and finally step pool. There is an increase in the W/D ratio downstream of the woody debris at ~106 m distance. Along the step pool reach there are various bedrock exposures that have caused the W/D ratio immediately upstream to increase significantly. I propose that the immediate upstream segments from bedrock exposures are being eroded as the stream hits the more resistant material.

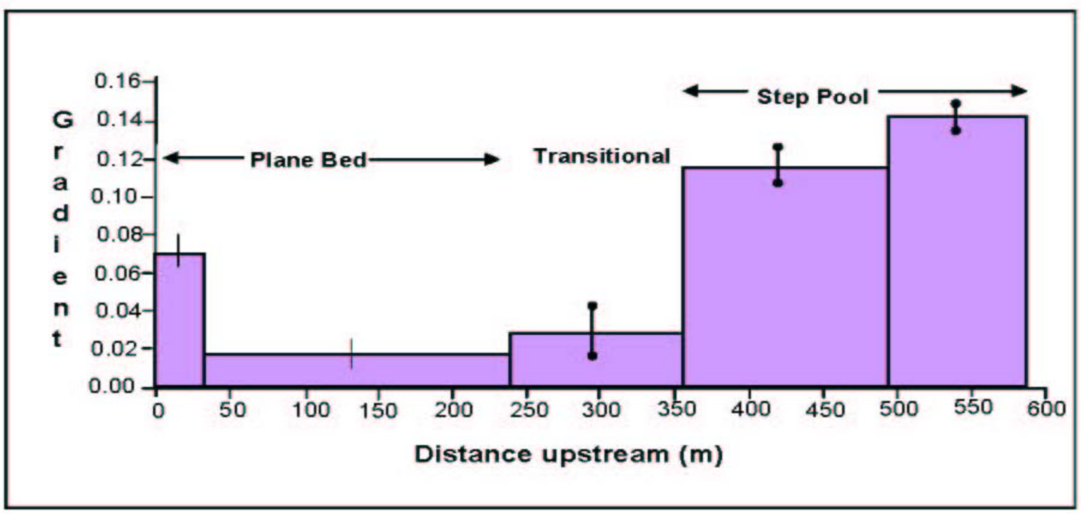


Figure 3. This bar chart is the averaged gradients for similar gradient slopes, as seen on the longitudinal profile at Sandy Pond. The gradient increases at the delta but there is a general decrease of average gradient downstream. The standard deviation for each bar is drawn at the center of the purple bars.

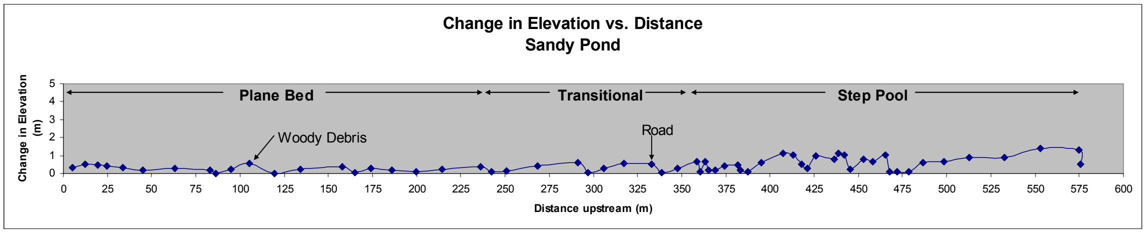


Figure 4. The change in elevation between subsequent points is displayed. There upper reaches, step pool and transitional have greater changes in elevation than plane bed which has little change in elevation.

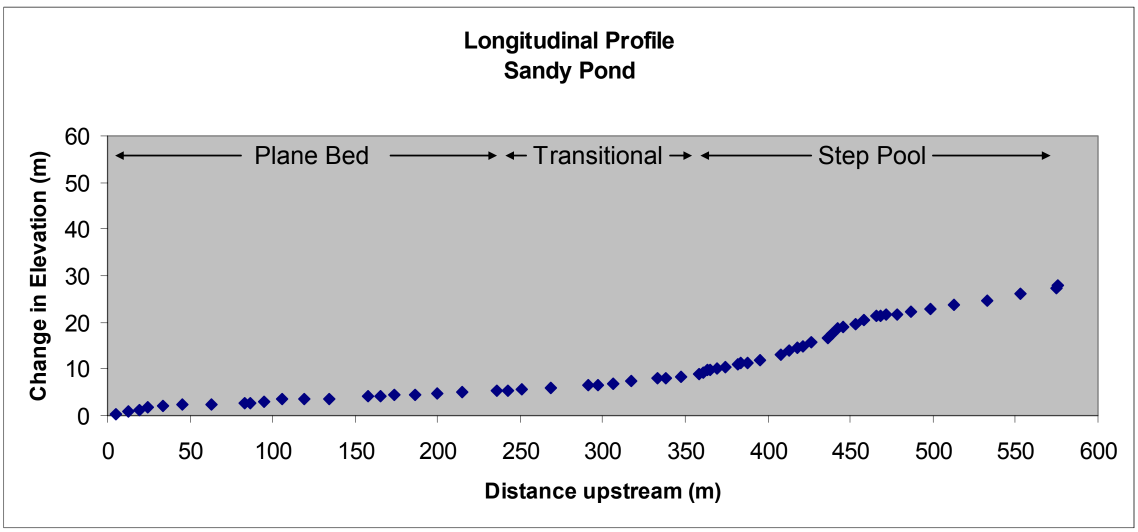
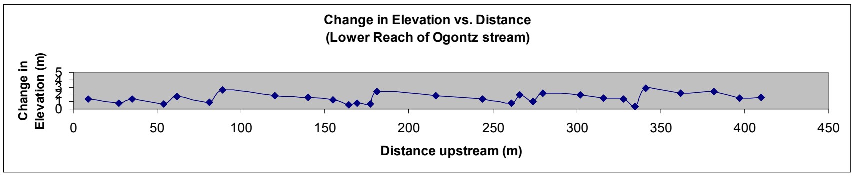


Figure 5. This represents the longitudinal profile of the stream bottom. The upstream reaches of step pool have significantly steeper slopes than the plane bed reach downstream. The dramatic decrease in elevation beginning at ~ 475 m could be due to a bedrock controlled streambed, although further study at Sandy stream would need to be done to confirm this idea. The change in elevation scale is much more than the largest data point to remain consistent with the longitudinal profiles at Ogontz stream.



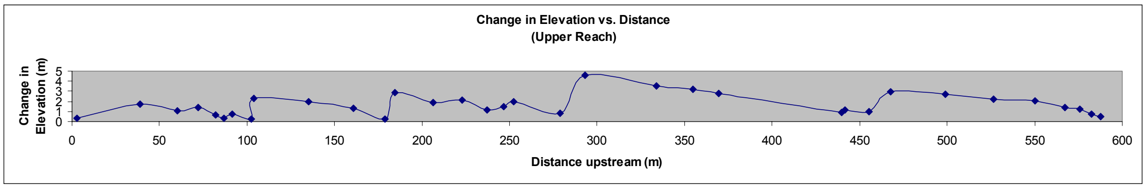
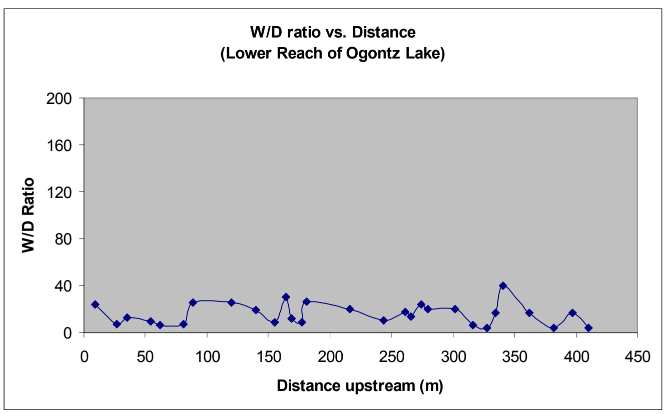


Figure 6. The step pool reach that dominates both the upper and lower stretches are beautifully displayed in this profile. The steps and pools become smaller downstream and may hint that the stream type is beginning to transition to a plane bed morphology.



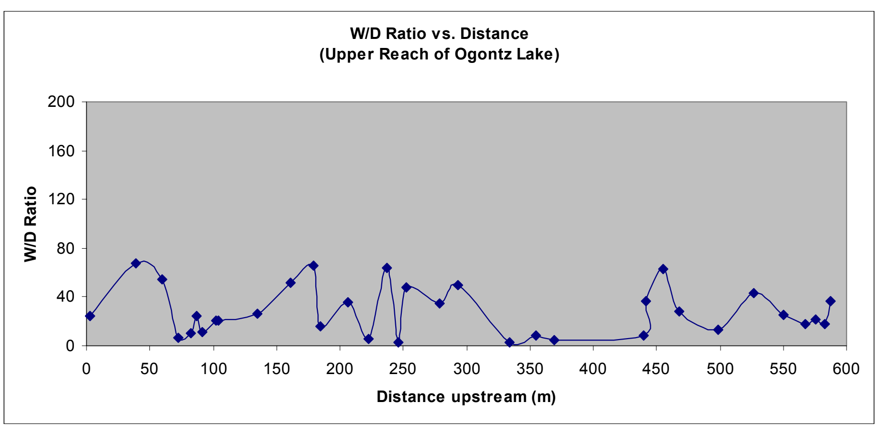
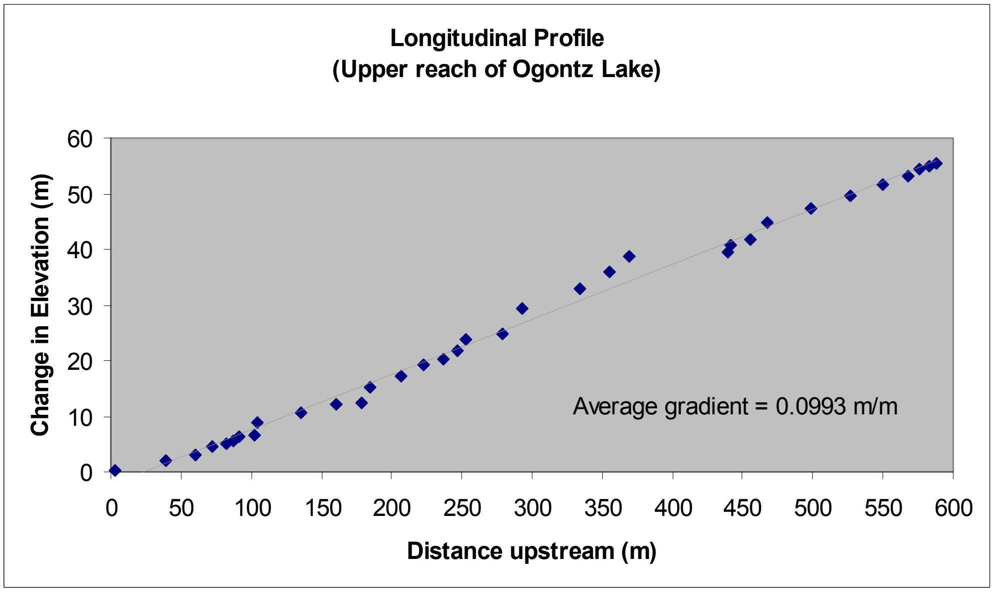


Figure 7. The high values for W/D ratio correspond with steps and low values correspond with pools. There is a lot of variability in the W/D ratios, but the high fluctuations decrease in the lower reach.



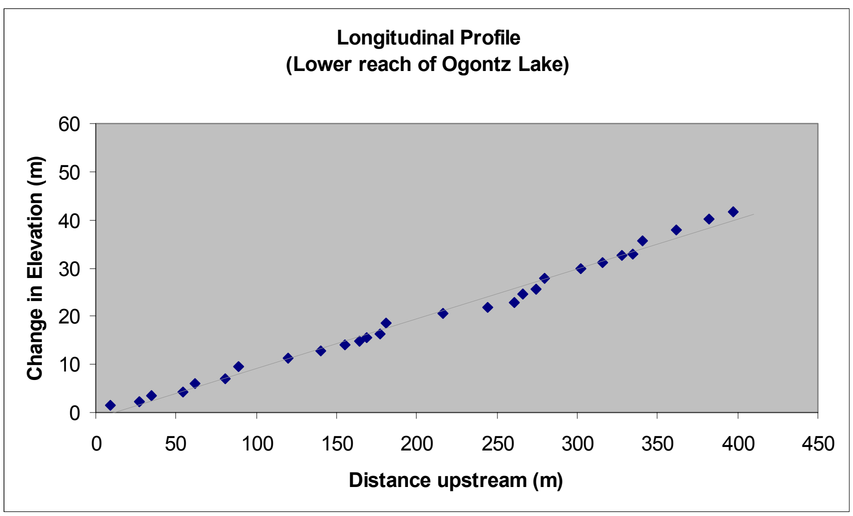


Figure 8. Both upper and lower reaches of Ogontz stream have a linear trend that decreases downstream.

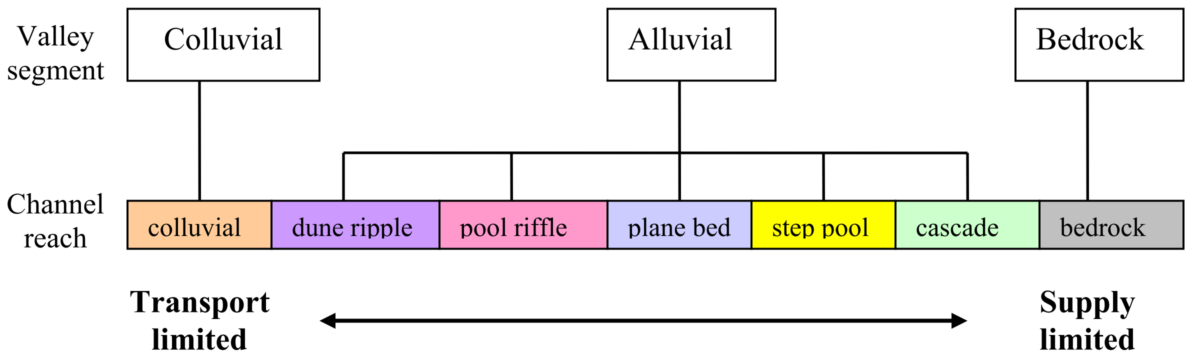


Figure 9. Schematic illustration of the transport capacities relative to sediment supply for reach-level channel types. Source: Montgomery and Buffington (1997)

APPENDIX
Ogontz Lake

Instrument Height	Center	Change in Elevation	Top	Bottom	Top-Bottom (Distance)	Sum of Distances	Actual Distance	Depth	Width	W/D	Gradient
1.515	2.025	0.51	2.04	2.01	0.03	0.03	3	0.135	5	37.04	0.17
1.515	2.215	0.7	2.24	2.19	0.05	0.08	8	0.025	4.5	180	0.14
1.515	2.755	1.24	2.79	2.725	0.065	0.145	14.5	0.21	4.5	21.43	0.1907692
1.515	2.885	1.37	2.93	2.84	0.085	0.23	23	0.025	4.5	180	0.1611765
1.515	3.605	2.09	3.7	3.52	0.175	0.405	40.5	0.085	2.15	25.29	0.1194286
1.515	3.765	2.25	3.89	3.65	0.235	0.64	64	0.05	2.15	43	0.0957447
1.515	4.195	2.68	4.35	4.075	0.275	0.915	91.5	0.165	2.15	13.03	0.0974545
1.515	4.5	2.985	4.66	4.34	0.315	1.23	123	0.075	2.1	28	0.0947619
1.64	2.62	0.98	2.68	2.56	0.12	1.35	135	0.03	1.9	63.33	0.0816667
1.53	2.685	1.155	2.75	2.61	0.14	1.49	149	0.06	2.2	36.67	0.0825
1.59	2.46	0.87	2.47	2.45	0.02	1.51	151	0.19	1.6	8.421	0.435
1.59	4.35	2.76	4.7	4	0.7	2.21	221	0.375	1.6	4.267	0.0394286
1.59	4.75	3.16	4.82	4.675	0.145	2.355	235.5	0.2	1.6	8	0.217931
1.59	5.115	3.525	5.22	5.01	0.21	2.565	256.5	0.65	2	3.077	0.1678571
1.59	6.17	4.58		5.965	0.41	2.975	297.5	0.04	2	50	0.1117073
1.61	2.47	0.86	2.54	2.4	0.14	3.115	311.5	0.09	3.1	34.44	0.0614286
1.61	3.57	1.96	3.7	3.435	0.265	3.38	338	0.065	3.1	47.69	0.0739623
1.64	3.155	1.515	3.19	3.125	0.06	3.44	344	0.465	1.5	3.226	0.2525
1.64	2.81	1.17	2.86	2.76	0.095	3.535	353.5	0.05	3.2	64	0.1231579
1.64	3.735	2.095	3.81	3.665	0.14	3.675	367.5	0.255	1.5	5.882	0.1496429
1.64	3.545	1.905	3.63	3.46	0.165	3.84	384	0.05	1.8	36	0.1154545
1.64	4.525	2.885		4.415	0.22	4.06	406	0.14	2.3	16.43	0.1311364
1.65	1.89	0.24	1.92	1.86	0.055	4.115	411.5	0.055	3.6	65.45	0.0436364
1.65	2.985	1.335	3.07	2.89	0.18	4.295	429.5	0.05	2.6	52	0.0741667
1.65	3.59	1.94	3.72	3.46	0.26	4.555	455.5	0.06	1.6	26.67	0.0746154
1.65	3.93	2.28	4.09	3.78	0.31	4.865	486.5	0.1	2.1	21	0.0735484
1.655	1.91	0.255	1.92	1.9	0.015	4.88	488	0.145	3	20.69	0.17
1.655	2.42	0.765	2.48	2.365	0.11	4.99	499	0.09	1	11.11	0.0695455
1.65	1.965	0.315	1.99	1.945	0.045	5.035	503.5	0.075	1.8	24	0.07
1.65	2.265	0.615	2.29	2.24	0.05	5.085	508.5	0.19	2	10.53	0.123
1.65	3.065	1.415	3.12	3.015	0.1	5.185	518.5	0.42	2.7	6.429	0.1415
1.65	2.74	1.09	2.8	2.68	0.12	5.305	530.5	0.05	2.7	54	0.0908333

1.65	3.36	1.71	3.26		0.21	5.515	551.5	0.02	2.7	135	0.0814286
1.64	1.985	0.345	2.3	1.94	0.36	5.875	587.5	0.07	1.7	24.29	0.0095833
1.445	2.87	1.425						0.235	1.7	7.234	
1.445	3.28	1.835						0.32	1.7	5.313	
1.665	2.725	1.06						0.14	1.5	10.71	
1.665	2.81	1.145						0.03	1.5	50	
1.62	2.915	1.295						0.345	2.8	8.116	
1.62	2.86	1.24						0.07	2.8	40	
1.62	3.59	1.97						0.19	2.8	14.74	
1.62	4.05	2.43						0.15	2.8	18.67	
1.62	4.55	2.93						0.35	2.1	6	
1.625	2.375	0.75						0.225	1.2	5.333	
1.625	2.585	0.96						0.17	1.7	10	
1.625	3.125	1.5						0.14	1.8	12.86	
1.625	3.11	1.485						0.04	1.2	30	
1.625	3.81	2.185						0.145	1.2	8.276	
1.625	4.095	2.47						0.06	1.2	20	
1.65	2.405	0.755						0.165	1.5	9.091	
1.65	3.195	1.545		3.15	0.09	0.09	9	0.275	1.2	4.364	0.1716667
1.65	3.165	1.515		3.1	0.13	0.22	22	0.07	1.2	17.14	0.1165385
1.65	3.995	2.345		3.92	0.15	0.37	37	0.31	1.2	3.871	0.1563333
1.65	3.85	2.2		3.75	0.2	0.57	57	0.07	1.2	17.14	0.11
1.65	4.49	2.84		4.385	0.21	0.78	78	0.03	1.2	40	0.1352381
1.655	1.975	0.32		1.945	0.06	0.84	84	0.07	1.2	17.14	0.0533333
1.655	2.975	1.32		2.94	0.07	0.91	91	0.33	1.2	3.636	0.1885714
1.655	3.115	1.46		3.055	0.12	1.03	103	0.19	1.2	6.316	0.1216667
1.655	3.58	1.925		3.51	0.14	1.17	117	0.06	1.2	20	0.1375
1.655	3.81	2.155		3.7	0.22	1.39	139	0.06	1.2	20	0.0979545
1.425	2.45	1.025		2.42	0.06	1.45	145	0.05	1.2	24	0.1708333
1.425	3.355	1.93		3.315	0.08	1.53	153	0.15	2	13.33	0.24125
1.535	2.375	0.84		2.35	0.05	1.58	158	0.1	1.8	18	0.168
1.535	2.88	1.345	2.97		0.17	1.75	175	0.095	1	10.53	0.0791176
1.535	3.41	1.875		3.27	0.28	2.03	203	0.1	2	20	0.0669643
1.535	3.965	2.43		3.79	0.35	2.38	238	0.075	2	26.67	0.0694286
1.565	2.23	0.665		2.21	0.04	2.42	242	0.33	3	9.091	0.16625
1.565	2.37	0.805		2.33	0.08	2.5	250	0.15	1.8	12	0.100625
1.555	2.165	0.61		2.14	0.05	2.55	255	0.065	2	30.77	0.122
1.555	2.85	1.295		2.805	0.09	2.64	264	0.23	2	8.696	0.1438889
1.555	3.1	1.545		3.025	0.15	2.79	279	0.12	2.3	19.17	0.103
1.555	3.345	1.79		3.245	0.2	2.99	299	0.03	3.3	110	0.0895
1.555	4.155	2.6		4	0.31	3.3	330	0.03	3.3	110	0.083871
1.6	2.565	0.965		2.525	0.08	3.38	338	0.17	1.2	7.059	0.120625
1.6	3.315	1.715		3.22	0.19	3.57	357	0.19	1.2	6.316	0.0902632
1.63	2.345	0.715		2.305	0.08	3.65	365	0.13	1.2	9.231	0.089375
1.63	2.99	1.36		2.895	0.19	3.84	384	0.095	1.2	12.63	0.0715789
1.645	2.44	0.795		2.4	0.08	3.92	392	0.16	1.2	7.5	0.099375
1.645	3.04	1.395		2.95	0.18	4.1	410	0.05	1.2	24	0.0775

Sandy Pond

Height	Center	Change in Elevation	Top	Bottom	Top-Bottom (Distance)	Actual Distance	Depth	Width	W/D	Gradient
1.420	1.730	0.3	1.755	1.71	0.05	5.0	0.44	1.94	4.4091	0.0620
1.420	1.920	0.5	1.955	1.88	0.08	12.5	0.62	1.55	2.5	0.0400
1.420	1.885	0.5	1.920	1.85	0.07	19.5	0.59	1.6	2.7119	0.0238
1.420	1.850	0.4	1.900	1.85	0.05	24.5	0.56	1.5	2.6786	0.0176
1.420	1.770	0.4	1.820	1.73	0.09	33.5	0.43	1.33	3.093	0.0104
1.420	1.610	0.2	1.665	1.55	0.12	45.0	0.32	1.33	4.1563	0.0042
1.420	1.690	0.3	1.790	1.61	0.18	63.0	0.4	1.35	3.375	0.0043
1.420	1.600	0.2	1.700	1.50	0.20	83.0	0.31	1.35	4.3548	0.0022
1.625	1.620	0.0	1.635	1.60	0.03	86.5	0.425	1.11	2.6118	0.0001

1.625	1.410	0.2	1.455	1.37	0.09	95.0	0.09	1.58	17.556	0.0023
1.625	1.085	0.5	1.135	1.03	0.11	105.5	0.155	1.54	9.9355	0.0051
1.625	1.610	0.0	1.680	1.54	0.14	119.5	0.67	1.54	2.2985	0.0001
1.625	1.400	0.2	1.470	1.33	0.15	134.0	0.45	1.54	3.4222	0.0017
1.625	1.245	0.4	1.360	1.12	0.24	158.0	0.315	1.32	4.1905	0.0024
1.565	1.605	0.0	1.640	1.57	0.07	165.0	0.515	1.21	2.3495	0.0002
1.565	1.280	0.3	1.325	1.23	0.09	174.1	0.4	1.65	4.125	0.0016
1.565	1.370	0.2	1.430		0.12	186.1	0.485	1.92	3.9588	0.0010
1.565	1.470	0.1	1.535	1.40	0.14	199.6	0.59	1.9	3.2203	0.0005
1.565	1.310	0.3	1.385		0.15	214.6	0.435	1.2	2.7586	0.0012
1.565	1.210	0.4	1.320	1.11	0.22	236.1	0.335	1.53	4.5672	0.0015
1.640	1.555	0.1	1.585	1.52	0.06	242.6	0.07	1.5	21.429	0.0004
1.640	1.480	0.2	1.520	1.44	0.09	251.1	0.12	1.3	10.833	0.0006
1.640	1.205	0.4	1.295	1.12	0.18	268.6	0.09	1.4	15.556	0.0016
1.640	1.050	0.6	1.120	0.90	0.23	291.1	0.05	1.35	27	0.0020
1.670	1.610	0.1	1.640	1.58	0.06	297.1	0.21	1.12	5.3333	0.0002
1.670	1.410	0.3	1.455	1.37	0.09	306.1	0.24	1.2	5	0.0008
1.670	1.125	0.5	1.180	1.07	0.11	317.1	0.09	2	22.222	0.0017
1.670	1.145	0.5	1.225	1.07	0.16	333.1	0.3	2.95	9.8333	0.0016
1.645	1.585	0.1	1.615	1.56	0.05	338.6	0.09	1.7	18.889	0.0002
1.645	1.370	0.3	1.415	1.33	0.09	347.6	0.12	1.3	10.833	0.0008
1.645	0.985	0.7	1.040	0.93	0.11	358.6	0.095	1.72	18.105	0.0018
1.720	1.605	0.1	1.615	1.60	0.02	360.6	0.14	2.1	15	0.0003
1.720	1.065	0.7	1.075	1.05	0.02	363.1	0.06	2.3	38.333	0.0018
1.560	1.395	0.2	1.405	1.39	0.02	365.1	0.05	2.13	42.6	0.0005
1.560	1.755	0.2	1.775	1.74	0.04	369.1	0.41	2	4.878	0.0005
1.560	1.120	0.4	1.145	1.10	0.05	374.1	0.02	2	100	0.0012
1.560	1.115	0.4	1.155	1.08	0.08	381.6	0.18	2	11.111	0.0012
1.690	1.510	0.2	1.515	1.50	0.01	383.1	0.05	1.9	38	0.0005
1.690	1.605	0.1	1.630	1.59	0.04	387.6	0.27	2.45	9.0741	0.0002
1.690	1.105	0.6	1.145	1.07	0.08	395.1	0.065	1.75	26.923	0.0015
1.690	0.575	1.1	0.635	0.51	0.13	407.6	0.01	2.7	270	0.0027
1.610	1.110	0.5	0.595	0.54	0.05	413.1	0.135	1.7	12.593	0.0012
1.635	1.290	0.3	1.140	1.09	0.05	418.1	0.155	1.28	8.2581	0.0008
1.560	0.560	1.0	1.305	1.28	0.03	421.1	0.17	1.5	8.8235	0.0024
1.560	0.770	0.8	0.585	0.54	0.05	426.1	0.015	1.63	108.67	0.0019
1.560	0.425	1.1	0.825	0.72	0.11	436.6	0.335	2.5	7.4627	0.0026
1.525	0.485	1.0	0.435	0.41	0.02	438.9	0.11	1.82	16.545	0.0024
1.525	1.330	0.2	0.500	0.47	0.03	441.9	0.175	1.82	10.4	0.0004
1.580	0.805	0.8	1.350	1.32	0.04	445.4	0.14	1.6	11.429	0.0017
1.580	0.925	0.7	0.825	0.75	0.08	452.9	0.03	1.6	53.333	0.0014
1.580	0.556	1.0	0.950	0.90	0.05	458.4	0.225	1.05	4.6667	0.0022
1.580	1.690	-0.1	0.595	0.53	0.07	465.4	0.065	1.72	26.462	-0.0002
1.585	1.585	0.0	1.705	1.68	0.03	467.9	0.195	1.75	8.9744	0.0000
1.685	1.580	0.1	1.605	1.57	0.04	471.9	0.135	1.35	10	0.0002
1.685	1.070	0.6	1.610	1.55	0.07	478.4	0.26	2.25	8.6538	0.0013
1.685	1.045	0.6	1.110	1.03	0.09	486.9	0.02	1	50	0.0013
1.685	0.785	0.9	1.105	0.99	0.12	498.4	0.145	1.4	9.6552	0.0018
1.685	0.810	0.9	0.855	0.71	0.15	512.9	0.075	1.05	14	0.0017
1.685	0.810	0.9	0.910	0.71	0.20	532.9	0.285	1.2	4.2105	0.0016
1.685	0.290	1.4	0.390		0.20	552.9	0.09	1.2	13.333	0.0025
1.685	0.370	1.3	0.480		0.22	574.9	0.17	1.1	6.4706	0.0023
1.770	1.240	0.5	1.245	1.24	0.01	575.9	0.06	1.1	18.333	0.0009