# To what extent does the Glenderaterra Beck follow the predictions of the Bradshaw Model?

## A RIVER FIELD WORK STUDY

Geography Internal Assessment | Assessment May 2020

[Word count: 2365]

## Contents

## Acknowledgements

I want to thank the Field Studies Council Fieldwork Centre in Blencathra for aid and guidance with the investigation and the data collection.

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# I. Fieldwork Question and Geographic Context

## A. HYPOTHESES

1) The particle size decreases, and shape increases as the river distances from the source due to attrition.

2) As the distance downstream increases, the Hydraulic Radius increases. That is because the river widens and deepens and therefore becomes more effective at transporting water.

3) The velocity does increase with distance downstream because tributaries join the river and add more water, increasing the speed of the flow.

## B. RELATION TO SYLLABUS

The study relates to Option A: Freshwater.

## C. GEOGRAPHY IN STUDY AREA

The Glenderaterra Beck is a river in the Northern Lake District in England, its source situated between the mountains Blencathra and Skiddaw, creating a steep valley. The mountains are 700 to 800m high at either side of the river. That makes it easy for rainwater to flow into said river.
The land around the upper part of the river is used for sheep farming, making it hard for trees to grow. Because of the low interception, this creates a further factor that contributes to the rather excessive flow of rainwater into the river.
Due to the maritime climate with lots of humid, windy and cold days, there is an abundance of relief rainfall. The about 1500mm rain per year create a risk of flooding, such as one in Keswick, a town just nearby, in 2009.

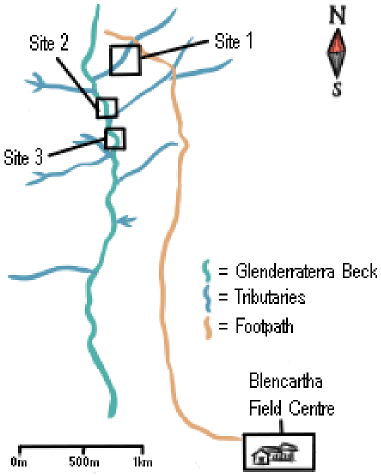


*Fig. 1: Map of the Glenderaterra Beck*

Not only the relief, land use and climate contribute to rising river levels, but also the geology. Around the Glenderaterra Beck there is a lot of slate, some rocks bigger than others. Because these rocks are impermeable, the speed of the water running down the hill increases, which then also leads to a higher discharge of water in the river.

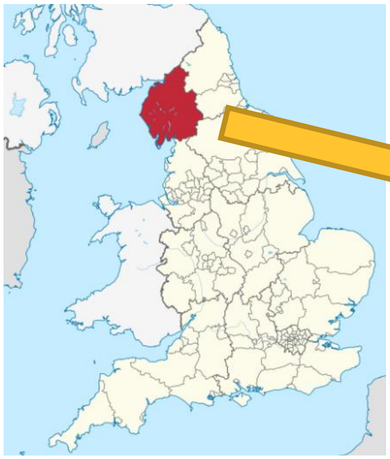


*Fig. 2: Cumbria in England* [1]

*Fig. 3: Cumbria - screenshot from Google Maps* [2]

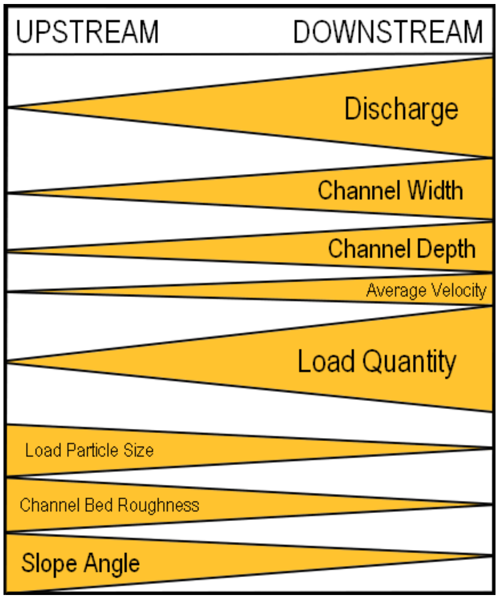


*Fig. 4: Bradshaw Model*

### D. GEOGRAPHIC THEORY

The Bradshaw Model describes a rivers characteristic and its variation between the upstream and downstream part of the river, for example as the river flows downstream the slope angle decreases.

The hypothesis formed states that the river studied does follow the predictions of the Bradshaw Model.

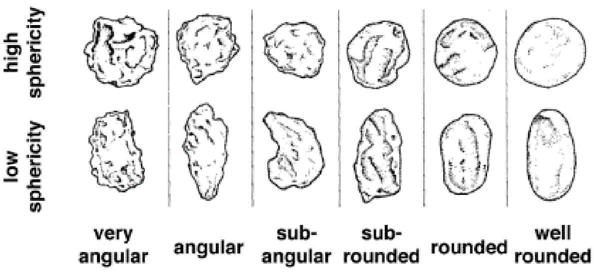
We must consider that not all variables increase by the same factor, which means that for example discharge and load quantity increase more radically than the average velocity.

However, the three variables that are supposed to decrease may decrease by the same or a similar factor.

## II. Methods of Investigation

### A. EQUIPMENT

*Fig. 5: Equipment*

| What data was collected? | How was the data collected? | Why was the data collected? |
|---|---|---|
| B. PARTICLE SIZE AND SHAPE | The width, length and depth of a rock or pebble is measured using a ruler. To determine the shape the Power's Roundness Index was used.<br><br> <br>*Fig.6: Power's Roundness Index* [3] *– 1 (left) to 6 (right)* | Due to attrition the rocks may be more rounded or angular. To measure the size and shape of rocks one can investigate if attrition happens altogether. |
| C. VELOCITY | An impeller is attached to a Hydroprop. This is placed into the water with reasonable depth. As soon as the impeller is covered by water, the time is recorded with a stopwatch. | The distance travelled by the impeller and the time measured is used to calculate the velocity. |
| D. WET WIDTH | Two people are measuring the width just above the river level using a tape measure. A third person is the recorder, meaning they keep track of the results. It is advisable to use the metric system.<br>The recorder either uses a system that automatically divides the width into ten values, or manually calculates them.<br>The depth is measured at those ten calculated points; therefore, the tape measure must be stretched across the river. A fourth person now uses a metre ruler and sticks it in at each of the ten points. It is easier to read off the results off the ruler if it's stuck into the water along the flow and not across. | Used to calculate the Cross-Section Area. |
| E. WET DEPTH | | Used to calculate the Cross-Section Area. |

| | | |
|---|---|---|
| F. WETTED PERIMETER | A chain is laid down on the riverbed, it's beginning at the top of the bank. After fully placed in the water, across the river, the chain will be laid up the riverbank. The wetted perimeter is determined by holding the chain's point where it got out at the bank and measure the length from start to there. | Used to calculate the Hydraulic Radius. |

## G. SAMPLING STRATEGIES

A stratified strategy was used to collect the data, meaning that a proportional number of measurements was taken in each area. The data is measured after each tributary joins the river.

This strategy is quicker than others as more data can be collected in the time provided.

There were only three sites of data collection, all situated with low distance downstream. This can be seen as a limitation to the study; however, trends can still be established with the three sites being upstream.

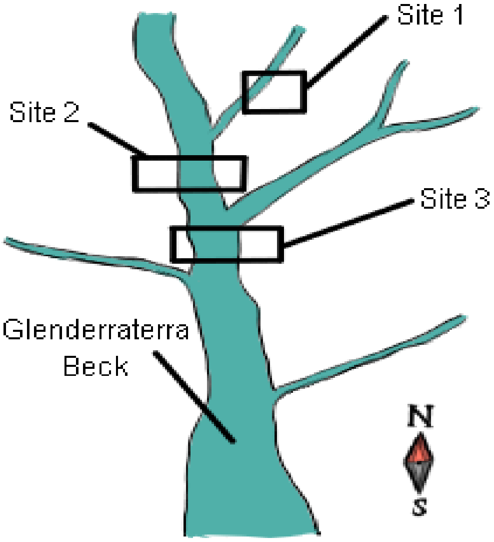


*Fig. 7: Stratified Strategy*

## III. Hypothesis 1 – Particle Size and Shape

**Null Hypothesis ($H_0$): There is no relationship between distance downstream and particle size/shape.**

**Alternative Hypothesis ($H_1$): The particle size and shape decrease as the river distances from the source.**

To investigate the change in particle size and shape, I will look at both factors individually. The data used for all figures can be found in the appendices.

### A. PARTICLE SIZE

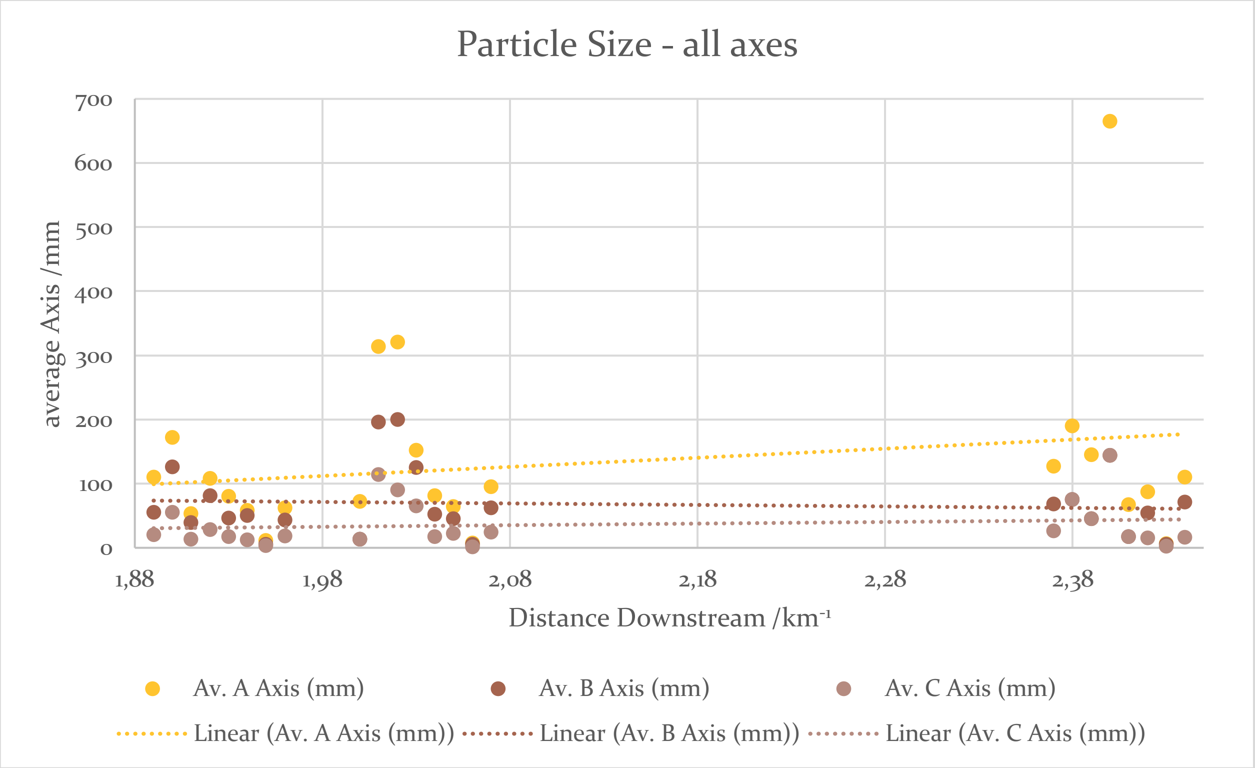


*Fig. 8: Particle Size – all axes*

The Axes B and C are decreasing throughout the sites, whereas Axis A is increasing. I will go into detail about this effect in the section “b. Particle Shape”.

I believe that in order to establish an actual correlation between the distance from the source and the particle size, it would be more useful to work in volume rather than in lengths of particle axes. Hence, I will use volume to maximise the possibility of a correct result. I will not look at the sites individually, because there might be a negative trend at each site, but an overall positive trend. This will increase the hopes of a correct result.

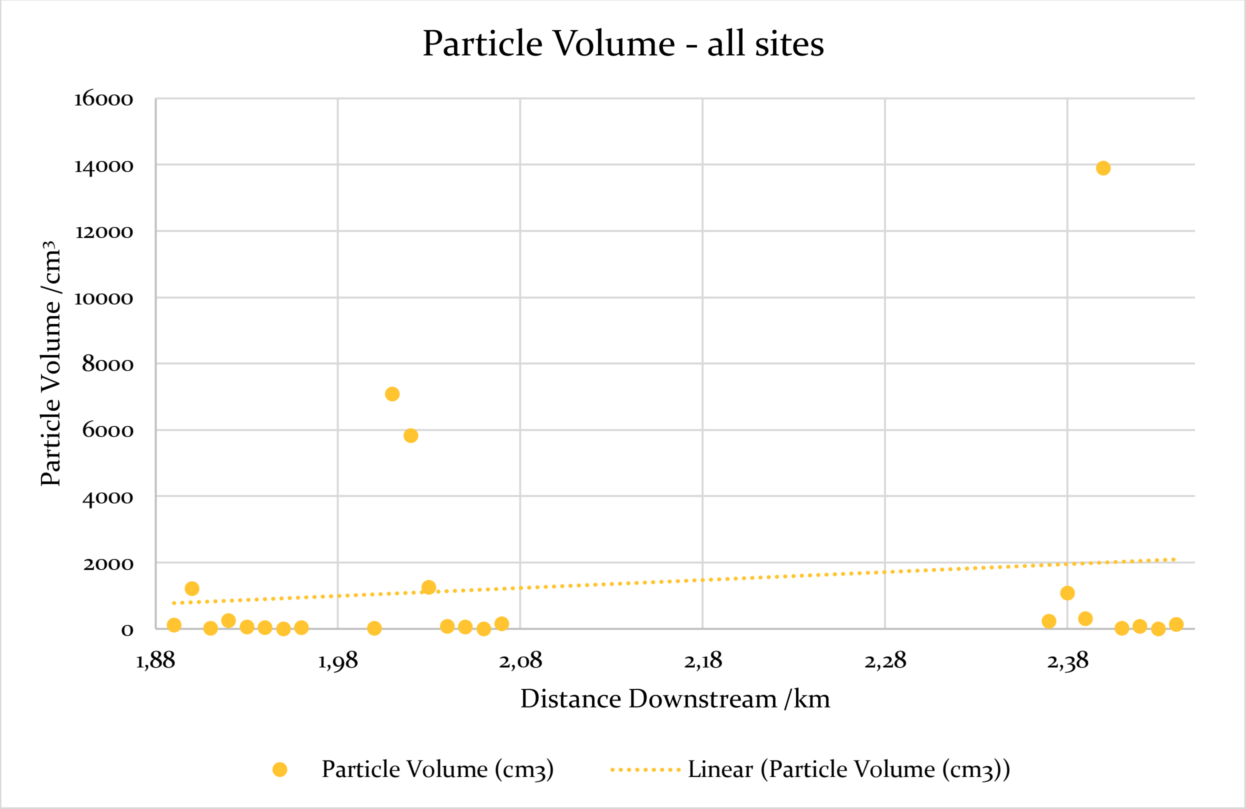


*Fig. 9: Particle Volume*

There is an overall positive trend, although a weak one, it seems. It is skewed into the positive by outliers, e.g. at (2.01|7085.21), (2.02|5823.65) and (2.40|13,895.81). These anomalies could have been caused by particles fallen or thrown into the river by animals or hikers. These result do not meet the predictions of the Bradshaw Model.

The Spearman's Rank Correlation Coefficient for this set of values is 0.03. This is a very weak value, which does not exceed the required value of 0.409 at *n* = 24, therefore I will have to accept the null hypothesis, i.e. there is no significant correlation between particle size and distance downstream.

## B. PARTICLE SHAPE

The particle shape is determined using the "*Power's Roundness Index*" (see Methodology). This shows us how angular and how spherical the particle is.

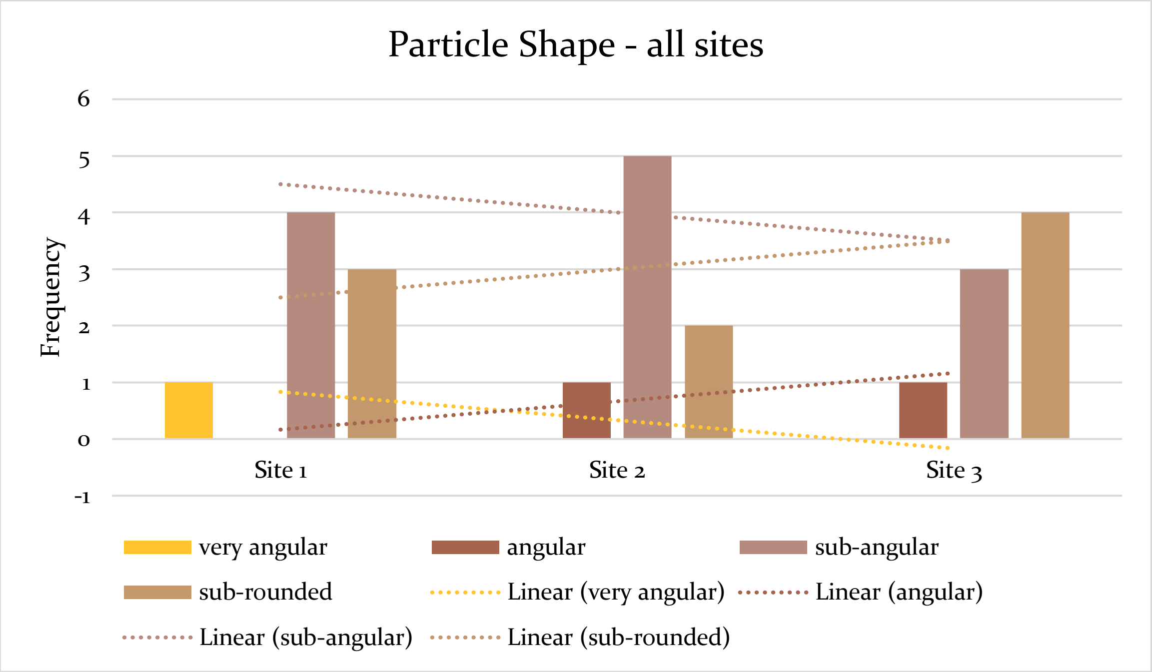


*Fig. 10: Distribution of Particle Shapes*

There is not much variation between the particles collected from different distances downstream, they are all either sub-angular or sub-rounded. An exception is a particle at site 1, which is surprisingly very angular. The Bradshaw Model predicts that the particles, as well as getting smaller, smooth out with distance downstream. A possibility is that the particle was transferred into the water more recently than the other particles, probably through external influence. When looking at Fig. 6 (Particle Size), at $x = 1.95$, we can see that the same particle was the smallest collected at that site. This may be an explanation, because smaller particles can travel easier for longer distances without experiencing as much attrition as larger particles as they have less surface area.

Picking up the before mentioned axes A, B and C, I have noticed that the trends are also showing, or at least indicating, the shapes or the particles. There is an increase in Axis A (longitudinal), but a decrease in Axis B (latitudinal) throughout the sites. This could indicate that the particles get more oblong and less rounded, i.e. their sphericity decreases.

Concluding, the particles get smoother throughout the sites, but their sphericity decreases.

## IV. Hypothesis 2 – Hydraulic Radius

**Null Hypothesis ($H_0$): There is no correlation between distance downstream and the Hydraulic Radius.**

**Alternative Hypothesis ($H_1$): As the distance downstream increases, the Hydraulic Radius increases with it.**

The hydraulic radius is a measure to determine how effective a river is flowing and how efficiently it transports water. It is calculated by dividing the Cross-Section Area by the Wetted Perimeter.

For example, the Hydraulic Radius at 1.89km distance from the source is calculated as follows:

$$\text{Hydraulic Radius} = \frac{Cross-Section\ Area}{Wetted\ Perimeter} = \frac{Wet\ Width \times Wet\ Depth}{Wet\ Width + 2(Wet\ Depth)}$$

$$= \frac{(2.51 \times 0.05)}{2.51 + 2(0.05)} = \frac{0.1255}{2.61}$$

$$= \underline{0.0480}$$

All values for the hydraulic radius are displayed in Figure 9.

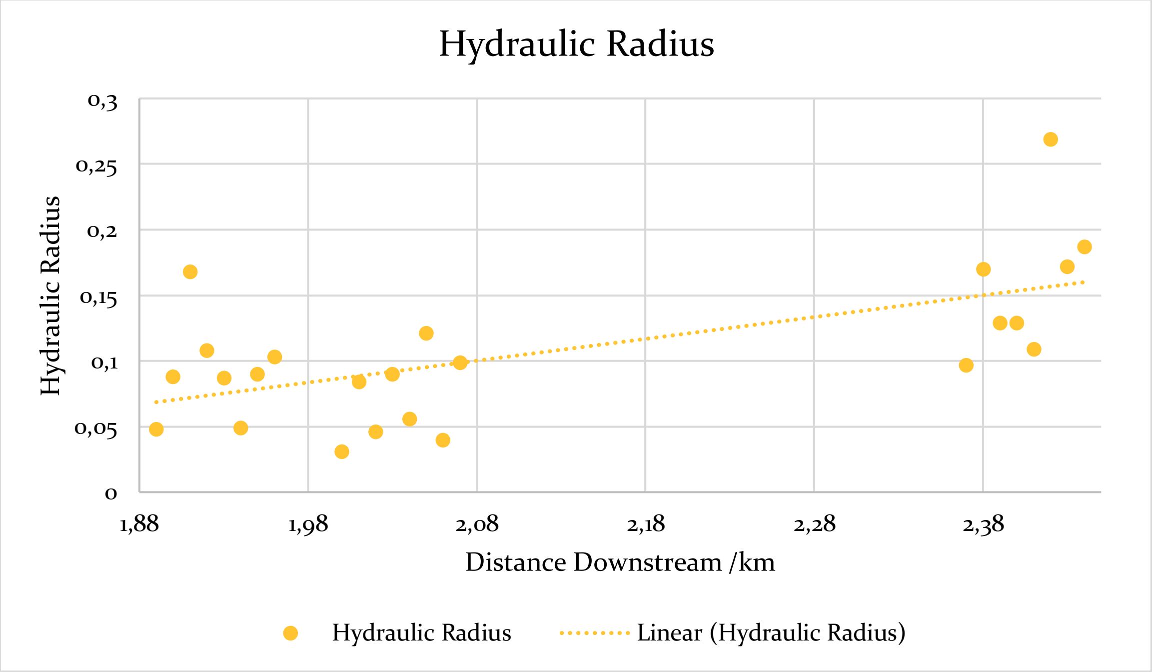


*Fig. 11: Hydraulic Radius*

It is clear to see that there is an overall increase in Hydraulic radius, meaning that as the river commences, it becomes more efficient as transporting water. This is because the river gets wider and deeper with distance downstream, as predicted by the Bradshaw Model. However, to achieve the maximum efficiency potential, the cross-section area must be large, whereas the wetted perimeter must be kept small. This assures the highest possible value for the hydraulic radius, therefore the highest efficiency.

Although the overall trend in increasing, the river would not have such a high increase in hydraulic radius, because the data points (1.91|0.168) and (2.42|0.269) are influencing the correlation and skewing the coefficient into the positive. These anomalies could have been caused but sudden widenings of the river due to tributaries joining or curving of the riverbanks.

As shown by the graph, there is a definite increase, however, to establish if this means I can reject the null hypothesis, I am going to use the Spearman's Rank correlation coefficient (see Appendix b.).

| **Independent variable (x)** | **Rank ($R_x$)** | **Dependent variable (y)** | **Rank ($R_y$)** | **D ($R_x$-$R_y$)** | **$D^2$** |
|---|---|---|---|---|---|
| **1.89** | 1 | 0.048 | 4 | -3 | 9 |
| **1.90** | 2 | 0.088 | 9 | -7 | 49 |
| **1.91** | 3 | 0.166 | 20 | -17 | 289 |
| **1.92** | 4 | 0.108 | 15 | -11 | 121 |
| **1.93** | 5 | 0.087 | 8 | -3 | 9 |
| **1.94** | 6 | 0.049 | 5 | 1 | 1 |
| **1.95** | 7 | 0.090 | 10.5 | -3.5 | 12.25 |
| **1.96** | 8 | 0.103 | 14 | -6 | 36 |
| **2.00** | 9 | 0.031 | 1 | 8 | 64 |
| **2.01** | 10 | 0.084 | 7 | 3 | 9 |
| **2.02** | 11 | 0.046 | 3 | 8 | 64 |
| **2.03** | 12 | 0.090 | 10.5 | 1.5 | 2.25 |
| **2.04** | 13 | 0.056 | 6 | 7 | 49 |
| **2.05** | 14 | 0.121 | 17 | -3 | 9 |
| **2.06** | 15 | 0.040 | 2 | 13 | 169 |
| **2.07** | 16 | 0.099 | 13 | 3 | 9 |
| **2.37** | 17 | 0.097 | 12 | 5 | 25 |
| **2.38** | 18 | 0.170 | 22 | -4 | 16 |
| **2.39** | 19 | 0.129 | 18.5 | 0.5 | 0.25 |

| | | | | | |
|---|---|---|---|---|---|
| **2.40** | 20 | 0.129 | 18.5 | 1.5 | 2.25 |
| **2.41** | 21 | 0.109 | 16 | 5 | 25 |
| **2.42** | 22 | 0.269 | 24 | -2 | 4 |
| **2.43** | 23 | 0.172 | 21 | 2 | 4 |
| **2.44** | 24 | 0.187 | 23 | 1 | 1 |
| | | | **Σ** | 0 | **979** |

$$R_s = 1 - \left(\frac{6(979)}{24^3 - 24}\right) = 1 - 0.43$$

$R_s$ = <u>0,57</u>

As the Spearman's Rank Correlation Coefficient for the hydraulic radius with respect to distance downstream is 0.57, and the critical value for 24 ranks is 0.409 (see appendix c), we can reject the null hypothesis of no correlation at a 95% confidence level. This means we can accept the alternative hypothesis ($H_1$), i.e. there is a positive correlation between distance downstream and the hydraulic radius.

It is important to notice that the river study indeed investigated changes of the Glenderaterra Beck downstream, but the area of investigation is relatively upstream. That means that although the test results say that the Hydraulic Radius increases with distance from the source, it might have a peak at a certain distance and then decrease again.

## V. Hypothesis 3 – Velocity

**Null Hypothesis ($H_0$): There is no correlation between distance downstream and velocity.**

**Alternative Hypothesis ($H_1$): The velocity increases with distance downstream.**

Velocity measures how fast a river flows. When a Hydroprop is used, the velocity is calculated as follows:

$Hydroprop\ Velocity = 0.0277 + \left(\frac{3.2805}{t\ in\ seconds}\right)$, where 3.2805 is the distance travelled by the impeller.

All obtained values for the Hydroprop velocity are displayed in Figure 10.

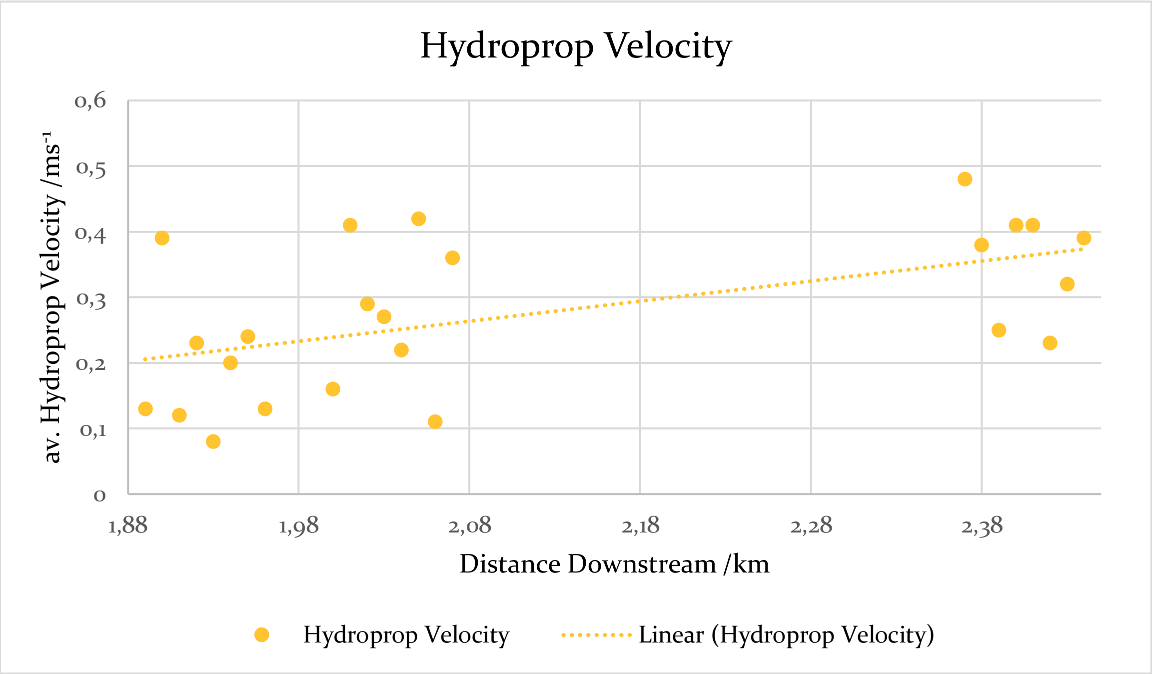


*Fig. 12: Hydroprop Velocity*

A definite positive trend can be seen. There is an outlier present at (1.90|0.39), where the velocity is higher than at the rest of the site. At site 2, the velocities measured have more variation in their values - some are higher, some are lower. This makes it harder to establish outliers. At site 3, a similar problem is present. I will treat the data as if there is only one outlier, however, an explanation for the variating values is that the velocity might have been measured behind a rock, which would lower the value at that distance downstream, as the rock would interfere with the flow of the water and slow it down. On the other hand, higher velocity values could have arisen due to free flow of water without any interference.

The Spearman's Rank Correlation Coefficient ($R_s$) for the correlation of Hydroprop velocity and distance downstream is 0.51. This exceeds the critical value of 0.409 at $n = 24$, therefore the null hypothesis can be rejected at a 95% confidence level. This means that there is a significant positive correlation between distance downstream and Hydroprop velocity.

## VI. Conclusion

Summary of results:

- The particle size did not increase significantly, but the shape did change as predicted.
- There is a significant positive correlation between hydraulic radius and distance downstream.
- There is a significant positive correlation between velocity and distance downstream.

Firstly, the particle size has increased over the three sites, when it was predicted to decrease. Although the shape has changed into the rounded direction, thus higher values on Power's Roundness Index, the initial hypothesis of the particle size decreasing and the shape increasing had to be rejected, as not all requirements to make the statement true have been fulfilled.

Secondly, a positive correlation between hydraulic radius and distance downstream was proven. Although the Bradshaw Model does not specify how the hydraulic radius changes with distance from the source, with the river widening and deepening the hydraulic radius should increase up to a certain point.

Lastly, a positive correlation between velocity and distance downstream has been determined. With more tributaries joining the river, it gains water and therefore speed.

In general, it can be said that the Glenderaterra Beck follows the predictions of the Bradshaw Model to the extent of anything that has to do with purely the river, and not its bedload, falling into the predictions of the Bradshaw Model.

## VII. Evaluation

The data obtained in field studies is heavily influenced by the equipment and methods used. Because most data were collected by hand, errors are unavoidable, but the weather conditions play a major role in data collection as well. During the 3 day-stay at Blencathra Field Studies Centre, it has been raining non-stop, and that has influenced not only the results, but also the way data collected.

It was hard to read off results and because the rain has caused the water level in the river to rise, it was difficult to obtain results while trying to not soak all clothes. Also, the river was very fast, and additionally to difficulties in maintaining balance inside the river due to slippery bedload, it was hard to stand inside and measure values at the same time. However, the rain had done more damage to the clothes that to the data, so the values obtained were as reliable as if they would have been on a brighter day.

An aspect to mention is the sampling strategy. What would have given more precise results is if the sites were further apart to underline trends that can be seen on a larger scale instead within approximately 500 metres. I think another sampling strategy would have produced more data for analysis, however, given the time required and access to the river, this was not possible. A systematic strategy could have been a better option.

# References

[1] TUBS. “Cumbria in England.” *Cumbria*, Wikimedia Commons, 28 Nov. 2011, Retrieved from: de.wikipedia.org/wiki/Cumbria.
Accessed on 09.03.2020

[2] Google Maps. “Cumbria.” *Cumbria*, 2020, Retrieved from:
www.google.com/maps/place/Cumbria/@54.6313011,-3.0454932,9z/data=!4m5!3m4!1s0x48632ab0a13de7c5:0x16e1925b0544819a!8m2!3d54.5772323!4d-2.7974835.
Accessed on 09.03.2020

[3]: Saputra, Wardana. “A New Roundness Scale for Sedimentary Particles (after Powers).” *Problem Encountered When Producing Carbonate Sand Reservoir*, ResearchGate, May 2016, Retrieved from: www.researchgate.net/profile/Wardana_Saputra/publication/303702743/figure/fig4/AS:368119399895044@1464777912894/A-new-roundness-scale-for-sedimentary-particles-after-Powers.png.
Accessed on 20.03.2019

*Note: All figures except the ones referenced were produced by the student.*

# Appendices

## A. RAW DATA

| Site | Distance Downstream (km) | Wet Width (m) | Av. Depth (m) | Hydroprop Velocity (m/s) | Av. A Axis (mm) | Av. B Axis (mm) | Av. C Axis (mm) | Av. Power's Shape Index |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.89 | 2.51 | 0.05 | 0.13 | 110.80 | 55.80 | 20.60 | 3.00 |
| 1 | 1.90 | 1.61 | 0.10 | 0.39 | 172.70 | 126.40 | 55.50 | 4.00 |
| 1 | 1.91 | 1.44 | 0.20 | 0.12 | 54.10 | 40.10 | 14.20 | 3.00 |
| 1 | 1.92 | 1.78 | 0.14 | 0.23 | 108.20 | 81.90 | 28.60 | 4.00 |
| 1 | 1.93 | 2.25 | 0.09 | 0.08 | 80.50 | 47.00 | 17.40 | 4.00 |
| 1 | 1.94 | 163 | 0.06 | 0.20 | 58.50 | 50.30 | 12.90 | 3.00 |
| 1 | 1.95 | 1.05 | 0.09 | 0.20 | 11.40 | 6.20 | 3.50 | 1.00 |
| 1 | 1.96 | 2.30 | 0.15 | 0.13 | 62.50 | 43.60 | 18.70 | 3.00 |
| 2 | 2.00 | 4.42 | 0.03 | 0.16 | 72.70 | 14.10 | 14.10 | 4.00 |
| 2 | 2.01 | 4.00 | 0.10 | 0.41 | 314.50 | 195.90 | 115.00 | 3.00 |
| 2 | 2.02 | 3.92 | 0.06 | 0.29 | 321.20 | 199.90 | 90.70 | 2.00 |
| 2 | 2.03 | 3.48 | 0.11 | 0.27 | 152.20 | 125.50 | 65.40 | 3.00 |
| 2 | 2.04 | 4.20 | 0.06 | 0.22 | 81.70 | 52.20 | 17.80 | 3.00 |
| 2 | 2.05 | 2.20 | 0.15 | 0.42 | 64.80 | 46.20 | 23.10 | 4.00 |
| 2 | 2.06 | 3.14 | 0.05 | 0.11 | 8.10 | 5.50 | 2.00 | 3.00 |
| 2 | 2.07 | 3.05 | 0.12 | 0.36 | 95.40 | 63.00 | 24.80 | 3.00 |
| 3 | 2.37 | 6.65 | 0.10 | 0.48 | 127.50 | 27.00 | 27.00 | 2.00 |
| 3 | 2.38 | 7.20 | 0.18 | 0.38 | 190.00 | 75.50 | 75.50 | 3.00 |
| 3 | 2.39 | 5.38 | 0.14 | 0.25 | 145.50 | 45.80 | 45.80 | 4.00 |
| 3 | 2.40 | 5.70 | 0.15 | 0.41 | 665.50 | 144.50 | 144.50 | 4.00 |
| 3 | 2.41 | 4.00 | 0.16 | 0.41 | 68.10 | 18.20 | 18.20 | 3.00 |
| 3 | 2.42 | 6.95 | 0.31 | 0.23 | 87.20 | 16.10 | 16.10 | 4.00 |
| 3 | 2.43 | 7.45 | 0.18 | 0.32 | 6.50 | 5.50 | 2.40 | 4.00 |
| 3 | 2.44 | 3.20 | 0.20 | 0.39 | 110.60 | 71.60 | 17.00 | 3.00 |

## B. SPEARMAN'S RANK CORRELATION COEFFICIENT

$R_s = 1 - \left(\frac{6\sum D^2}{n^3 - n}\right)$; Where $R_s$ is the correlation coefficient, $D$ the difference between the ranks and $n$ the number of ranks.

## C. CRITICAL VALUES

| | **Confidence Levels** | |
|---|---|---|
| **Number of ranks (n)** | **95%** | **99%** |
| **5** | 1.000 | - |
| **6** | 0.886 | 1.000 |
| **7** | 0.786 | 0.929 |
| **8** | 0.738 | 0.881 |
| **9** | 0.683 | 0.883 |
| **10** | 0.648 | 0.818 |
| **11** | 0.623 | 0.794 |
| **12** | 0.591 | 0.780 |
| **13** | 0.566 | 0.745 |
| **14** | 0.545 | 0.716 |
| **15** | 0.525 | 0.689 |
| **16** | 0.507 | 0.666 |
| **17** | 0.409 | 0.645 |
| **18** | 0.476 | 0.625 |
| **19** | 0.462 | 0.608 |
| **20** | 0.450 | 0.591 |
| **21** | 0.438 | 0.576 |
| **22** | 0.428 | 0.562 |
| **23** | 0.418 | 0.549 |
| **24** | 0.409 | 0.537 |
| **25** | 0.400 | 0.526 |

## D. CALCULATIONS

$$R_s \text{ (particle volume)} = 1 - \left(\frac{6(2224)}{24^3 - 24}\right)$$

$$= 1 - (0.97)$$

$$= \underline{\underline{0.03}}$$

$$R_s \text{ (velocity)} = 1 - \left(\frac{6(1125.5)}{24^3 - 24}\right)$$

$$= 1 - (0.49)$$

$$= \underline{\underline{0.51}}$$