The University of Pittsburgh

Plotting Stream Cross-Section Changes Over Time in Panther Hollow

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Abstract
This study aimed to assess the changes in stream morphology and sediment dynamics over time at two cross-sections along Panther Hollow run stream in Pittsburgh. The laser level and tape measure were used to measure height and distance at each station. The area under the curve for each cross-section was calculated using R and the trapezoidal rule. The net sediment moved per 100-meter reach was determined by finding the difference between the cross-section areas and multiplying it by the channel width and reach length. The upper cross-section showed a minimal change in sediment load, while the lower cross-section showed significant changes due to manual sediment removal. The net sediment moved per meter over a 100-meter reach was found to be 2.872573 m3. These findings can aid in stream management and restoration efforts.

1. Introduction

High and low flows in a stream can change the morphology over time, as well as affect sediment loads. Cross-sections taken over time can outline a picture of how stream morphology has changed. This cross-section was conducted at two locations on the Panther Hollow run stream. Human activity has impacted both the shape and sediment loads in this stream, particularly through channeling rainwater runoff directly into the stream. Additionally, manual removal of sediment from the bank walls has severely impacted the morphology in a short amount of time.

2. Methods

2.1 Equipment preparation and set-up

For this lab, a laser level was used to project a straight line across the stream to the cross-section top. A long tape measure (meters) was run from one side of the stream bank to the other. This allowed for precise distance measurements to be taken at each station along the cross-section.

3.2 Making cross-section measurements

Once the laser level and tape measure were in place, a sensor corresponding to the laser was attached to the top of a telescopic measuring pole. When the sensor held a steady tone without beeping, the height measurement on the pole was recorded. Additionally, the distance measurements on the ground were recorded at each height station. This was conducted at both stations. A groundwater well was used as a consistent marker at both sites. The “edge of water” station was recorded for both sides of the stream at both stations.

2.2 Integration of each curve

To understand the sediment dynamic throughout the entire channel over time, the area under the older and newest curves was calculated in R for comparison. The curves were isolated onto a plain white background and loaded into R. Next, they were converted to grayscale and the pixel values were bound into a matrix. The physical dimensions in meters were then supplied. Pixel dimensions were calculated from the values stored in the matrix created above. The values were then converted from pixel to meters by dividing pixel width by the real-life width in meters. The same was done for height. Sequential x and y values were then extracted from the matrix for both the x and y values. Finally, the curves were integrated using the trapezoidal rule (‘trapz’ package in R). This calculated the entire area under the curve for each year.

2.3 Calculating net sediment

Calculating the net sediment moved over a 100-meter reach involved first finding the difference between the cross-section areas. This difference was calculated from the outputs in R. Next, the sediment moved per meter of channel width was calculated by dividing the net sediment moved by the channel width. Lastly, the net sediment per meter of channel width was multiplied by the channel width and the reach length (100 m).

3. Analysis and Discussion

3.1 Upper cross-section

The upper cross-section was much more consistent with past measurements from 2012 and 2013. Human intervention at this site was much less prevalent than at the lower cross-section. The left bank shifted by about a meter to the right. Overall dept stayed relatively consistent through the years. The right bank was carved out more than previous cross sections and shifted down in elevation by about 0.5 meters.

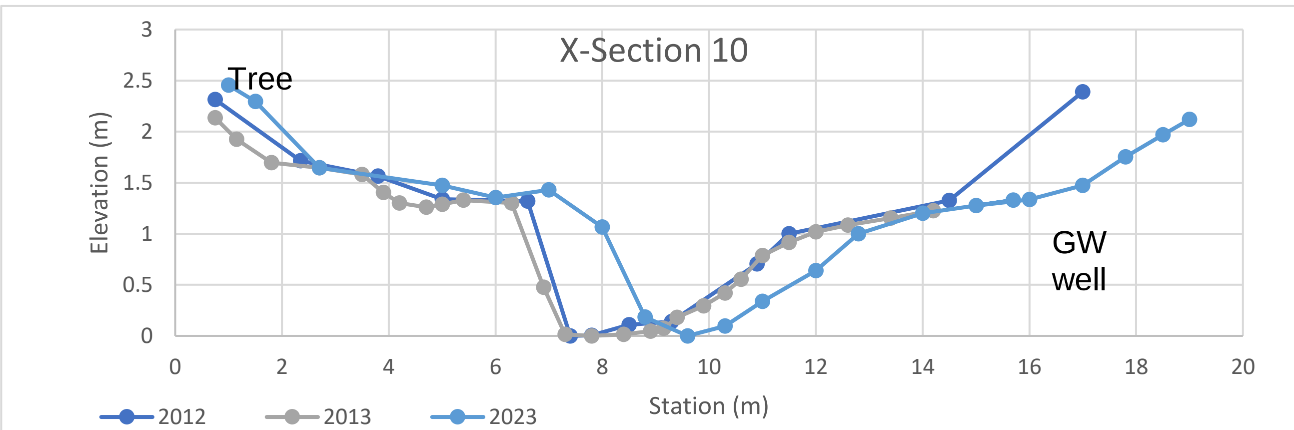

Figure 1 - Upper cross-section encompassing measurements from 2012, 2013, and 2023

The 2012 and 2023 curves were integrated independently and their values were compared. The 2012 area was 22.4017107404725 m^2 and the 2023 area was 22.4304364682093 m^2, the difference between them being 0.02872573 m^2.

3.2 Lower cross-section

The lower cross-section had been manually dug out by an earth mover since the last cross-section was taken in 2018. The left bank shifted to the right by about four meters and gained around 0.5 meters in height. The channel itself had been significantly flattened out, and the right bank was drastically higher than the previous measurements. The right bank shifted by about a meter and a half to the left and increased nearly a meter in height compared to 2018.

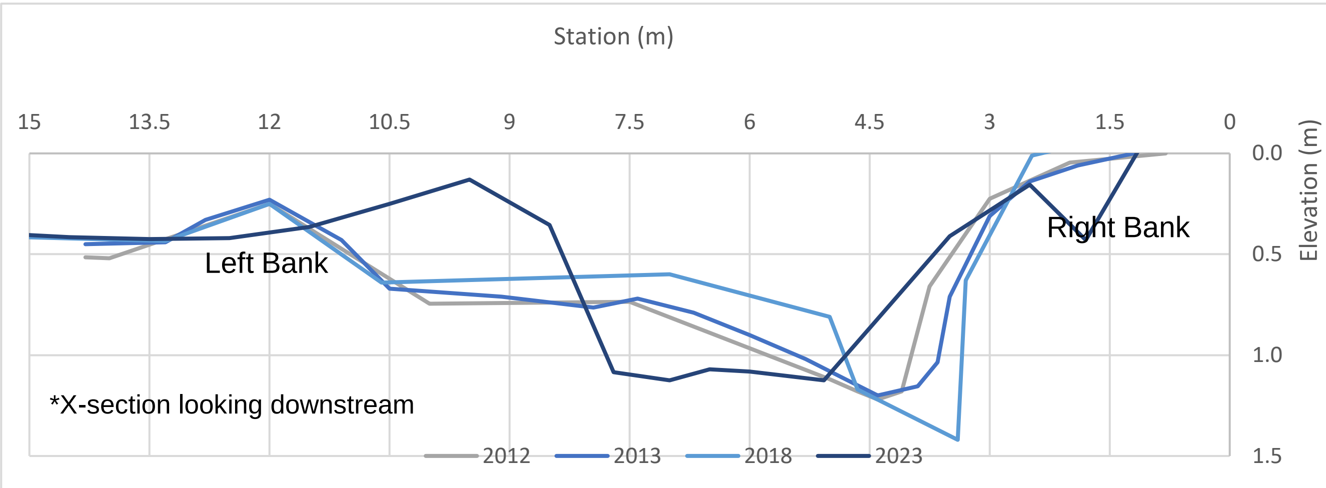

Figure 2 - Lower cross-section encompassing measurements from 2012, 2013, 2018, and 2023

The 2012 and 2023 curves were integrated independently. The area under the 2012 and 2023 curves was 59.8251617745264 m^2 and 59.6806937789479 m^2, respectively. This left a difference of 0.144468 m^2. Overall, the sediment load shifted in a small way, based on the total area under the curves.

The net sediment moved returned a value of 2.872573 m^3. This indicated that the net amount of sediment moved per meter over a 100-meter reach was around this volume. The years were kept consistent for this analysis (i.e., the 2023 values were used).

4. Conclusion

Based on the cross-sectional analysis of the Panther Hollow Stream, it is evident that human activity has significantly impacted the stream morphology, particularly through the channeling of rainwater runoff and manual removal of sediment from the bank walls. The lower cross-section was found to be more affected by human intervention, with a significant shift in bank positions and flattening out of the channel. In contrast, the upper cross-section showed more consistency with past measurements.

The area under the cross-sectional curves was calculated for each year, and the net sediment moved per 100-meter reach was determined to be around 2.87 cubic meters. These results indicate that even small-scale human activities can have a significant impact on stream morphology and sediment loads over time.

Overall, this study emphasizes the importance of considering human impacts on stream systems when evaluating and managing them. Further research and monitoring of the Panther Hollow stream could provide valuable insights into the long-term effects of human activities on stream morphology and sediment loads, which could inform management decisions aimed at preserving and enhancing the ecological health of the stream.

Appendix A: Source code

```
#Lab 3 cross-section integration


install.packages("imager")
install.packages("pracma")
library(imager)
library(dplyr)
library(pracma)
library(ggplot2)

#lower cross section
lower_cross_section2012 <- load.image("C:/Users/Thoma/OneDrive - University of
Pittsburgh/Spring Semester 2023/GEOL 1060 Geomorphology/Lab/Lab 3/lower 2012.jpg")
lower_cross_section2023 <- load.image("C:/Users/Thoma/OneDrive - University of
Pittsburgh/Spring Semester 2023/GEOL 1060 Geomorphology/Lab/Lab 3/lower 2023.jpg")

lower_gray2012 <- grayscale(lower_cross_section2012)
lower_gray2023 <- grayscale(lower_cross_section2023)

lower_pixel_values2012 <- as.matrix(gray2012, loc = TRUE)
lower_pixel_values2023 <- as.matrix(gray2023, loc = TRUE)

#define physical Dimension
lower_width_m_2012 <- 20
lower_height_m_2012 <- 3

lower_width_m_2023 <- 20
lower_height_m_2023 <- 3

#calculate pixel dimensions of images
lower_width_px2012 <- ncol(lower_pixel_values2012)
lower_height_px2012 <- nrow(lower_pixel_values2012)

lower_width_px2023 <- ncol(lower_pixel_values2023)
lower_height_px2023 <- nrow(lower_pixel_values2023)

#conversion factors from pixels to meters
lower_px_per_m_x2012 <- lower_width_px2012/lower_width_m_2012
lower_px_per_m_y2012 <- lower_height_px2012/lower_height_m_2012
```

```
lower_px_per_m_x2023 <- lower_width_px2023/lower_width_m_2023
lower_px_per_m_y2023 <- lower_height_px2023/lower_height_m_2023

#extract x and y matrix values
x2012_lower <- seq(0, lower_width_m_2012, length.out = lower_width_px2012)
y2012_lower <- apply(lower_pixel_values2012, 2, sum)/lower_px_per_m_y2012

x2023_lower <- seq(0, lower_width_m_2023, length.out = lower_width_px2023)
y2023_lower <- apply(lower_pixel_values2023, 2, sum)/lower_px_per_m_y2023


#calculate the area under the curve in m^2
lower_curve_area2012 <- trapz(x2012, y2012)
lower_curve_area2023 <- trapz(x2023, y2023)

print(paste0("Area under the curve in 2012: ", lower_curve_area2012, " m^2"))
print(paste0("Area under the curve in 2023: ", lower_curve_area2023, " m^2"))

lower_curve_dif <- lower_curve_area2023-lower_curve_area2012
print(lower_curve_dif)

lower_df2012 <- data.frame(x = x2012_lower, y = y2012_lower)
lower_df2023 <- data.frame(x = x2023_lower, y = y2023_lower)

ggplot() +
 geom_ribbon(data = lower_df2012, aes(x = x, ymin = 0, ymax = y), fill = "blue", alpha = 0.5) +
 geom_ribbon(data = lower_df2023, aes(x = x, ymin = 0, ymax = y), fill = "red", alpha = 0.5) +
 geom_line(data = lower_df2012, aes(x = x, y = y), color = "blue", size = 1) +
 geom_line(data = lower_df2023, aes(x = x, y = y), color = "red", size = 1) +
 scale_y_continuous(limits = c(2.8, 3)) +
 scale_x_continuous(limits = c(0, 20)) +
 labs(x = "Distance (m)", y = "Elevation (m)") +
 ggtitle("Lower Cross Section") +
 theme_bw()

# upper cross section

upper_cross_section2012 <- load.image("C:/Users/Thoma/OneDrive - University of
Pittsburgh/Spring Semester 2023/GEOL 1060 Geomorphology/Lab/Lab 3/upper 2012.jpg")
upper_cross_section2023 <- load.image("C:/Users/Thoma/OneDrive - University of
Pittsburgh/Spring Semester 2023/GEOL 1060 Geomorphology/Lab/Lab 3/upper 2023.jpg")
```

```
upper_gray2012 <- grayscale(upper_cross_section2012)
upper_gray2023 <- grayscale(upper_cross_section2023)

upper_pixel_values2012 <- as.matrix(upper_gray2012, loc = TRUE)
upper_pixel_values2023 <- as.matrix(upper_gray2023, loc = TRUE)

#define physical Dimension
upper_width_m_2012 <- 15
upper_height_m_2012 <- 1.5

upper_width_m_2023 <- 15
upper_eight_m_2023 <- 1.5

#calculate pixel dimensions of images
upper_width_px2012 <- ncol(upper_pixel_values2012)
upper_height_px2012 <- nrow(upper_pixel_values2012)

upper_width_px2023 <- ncol(upper_pixel_values2023)
upper_height_px2023 <- nrow(upper_pixel_values2023)

#conversion factors from pixels to meters
upper_px_per_m_x2012 <- upper_width_px2012/upper_width_m_2012
upper_px_per_m_y2012 <- upper_height_px2012/upper_height_m_2012

upper_px_per_m_x2023 <- upper_width_px2023/width_m_2023
uppeR_px_per_m_y2023 <- upper_height_px2023/height_m_2023

#extract x and y matrix values
x2012_upper <- seq(0, upper_width_m_2012, length.out = upper_width_px2012)
y2012_upper <- apply(upper_pixel_values2012, 2, sum)/upper_px_per_m_y2012

x2023_upper <- seq(0, upper_width_m_2023, length.out = upper_width_px2023)
y2023_upper <- apply(upper_pixel_values2023, 2, sum)/upper_px_per_m_y2023


#calculate the area under the curve in m^2
upper_curve_area2012 <- trapz(x2012, y2012)
upper_curve_area2023 <- trapz(x2023, y2023)

print(paste0("Area under the curve in 2012: ", upper_curve_area2012, " m^2"))
print(paste0("Area under the curve in 2023: ", upper_curve_area2023, " m^2"))
```

```
upper_curve_dif <- upper_curve_area2023-upper_curve_area2012
print(upper_curve_dif)

upperdf2012 <- data.frame(x = x2012, y = y2012)
upperdf2023 <- data.frame(x = x2023, y = y2023)

ggplot() +
  geom_ribbon(data = upperdf2012, aes(x = x, ymin = 0, ymax = y), fill = "blue", alpha = 0.5) +
  geom_ribbon(data = upperdf2023, aes(x = x, ymin = 0, ymax = y), fill = "red", alpha = 0.5) +
  geom_line(data = upperdf2012, aes(x = x, y = y), color = "blue", size = 1) +
  geom_line(data = upperdf2023, aes(x = x, y = y), color = "red", size = 1) +
  scale_y_continuous(limits = c(1.4, 1.5)) +
  scale_x_continuous(limits = c(0, 15)) +
  labs(x = "Distance (m)", y = "Elevation (m)") +
  ggtitle("Upper Cross Section") +
  theme_bw()

#net Sediment
net_sed_per_m_channel_lower <- lower_curve_dif/lower_width_m_2023
#100m reach
net_sed_100m_lower <- net_sed_per_m_channel_lower*lower_width_m_2023*100
print(net_sed_100m_lower)

net_sed_per_m_channel_upper <- upper_curve_dif/upper_width_m_2023
#100m reach
net_sed_100m_upper <- net_sed_per_m_channel_upper*upper_width_m_2023*100
print(net_sed_100m_upper)
```

Appendix B: Images used to pixelate integration

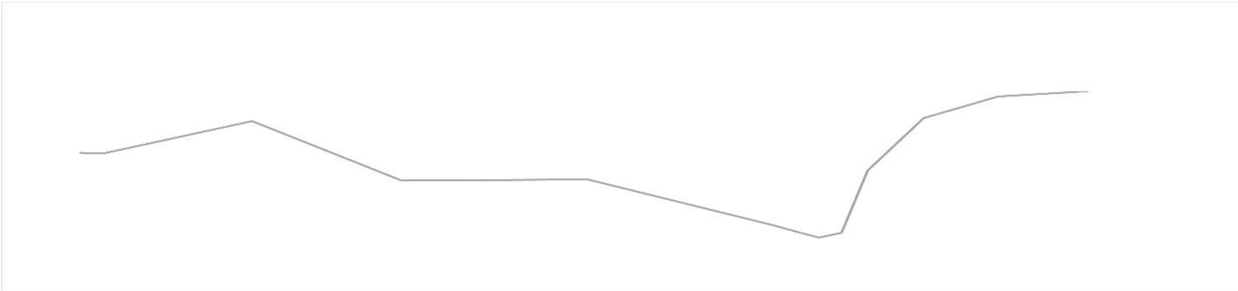

Figure 3 - Lower 2012 curve

Figure 4 - Upper 2012 curve

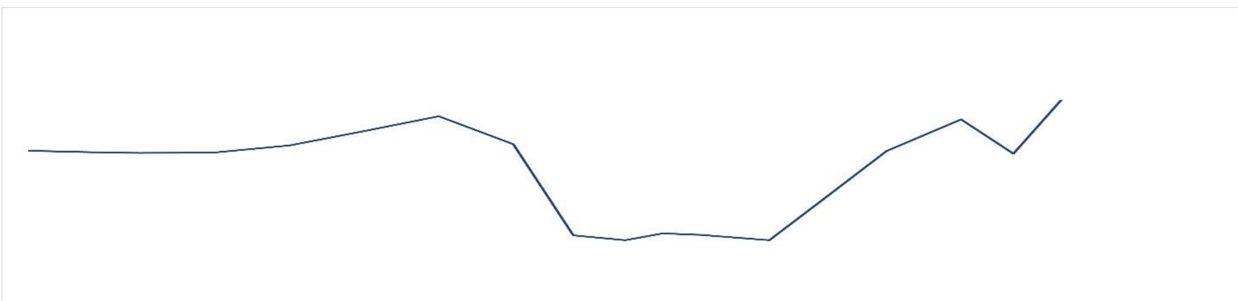

Figure 5 - Lower 2023 curve

Figure 6 - Upper 2023 curve

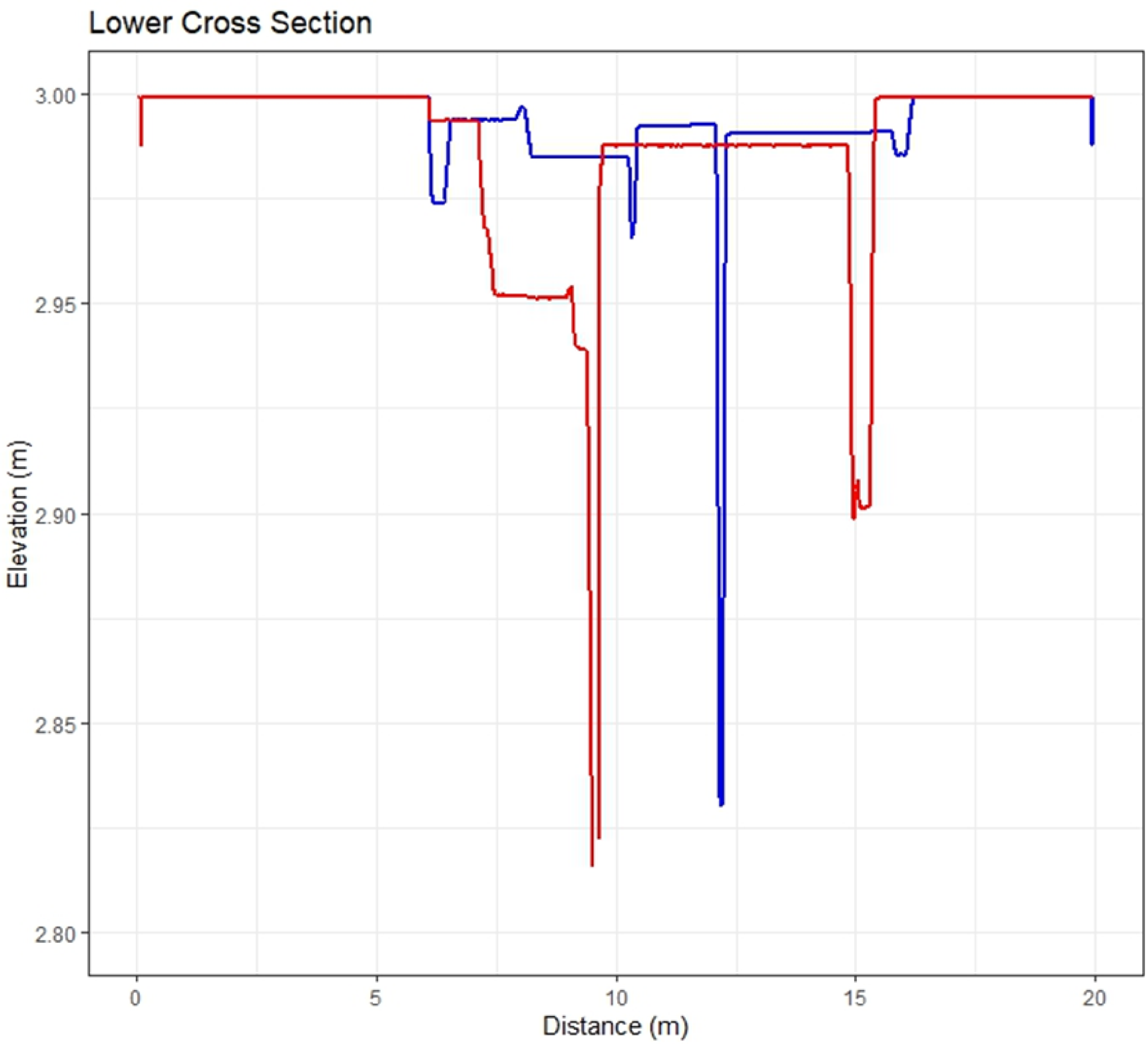

Figure 7 - Visualization created for the 2012 and 2023 from the lower cross-section pixel matrix in R. In blue is 2012 and in red is 2023

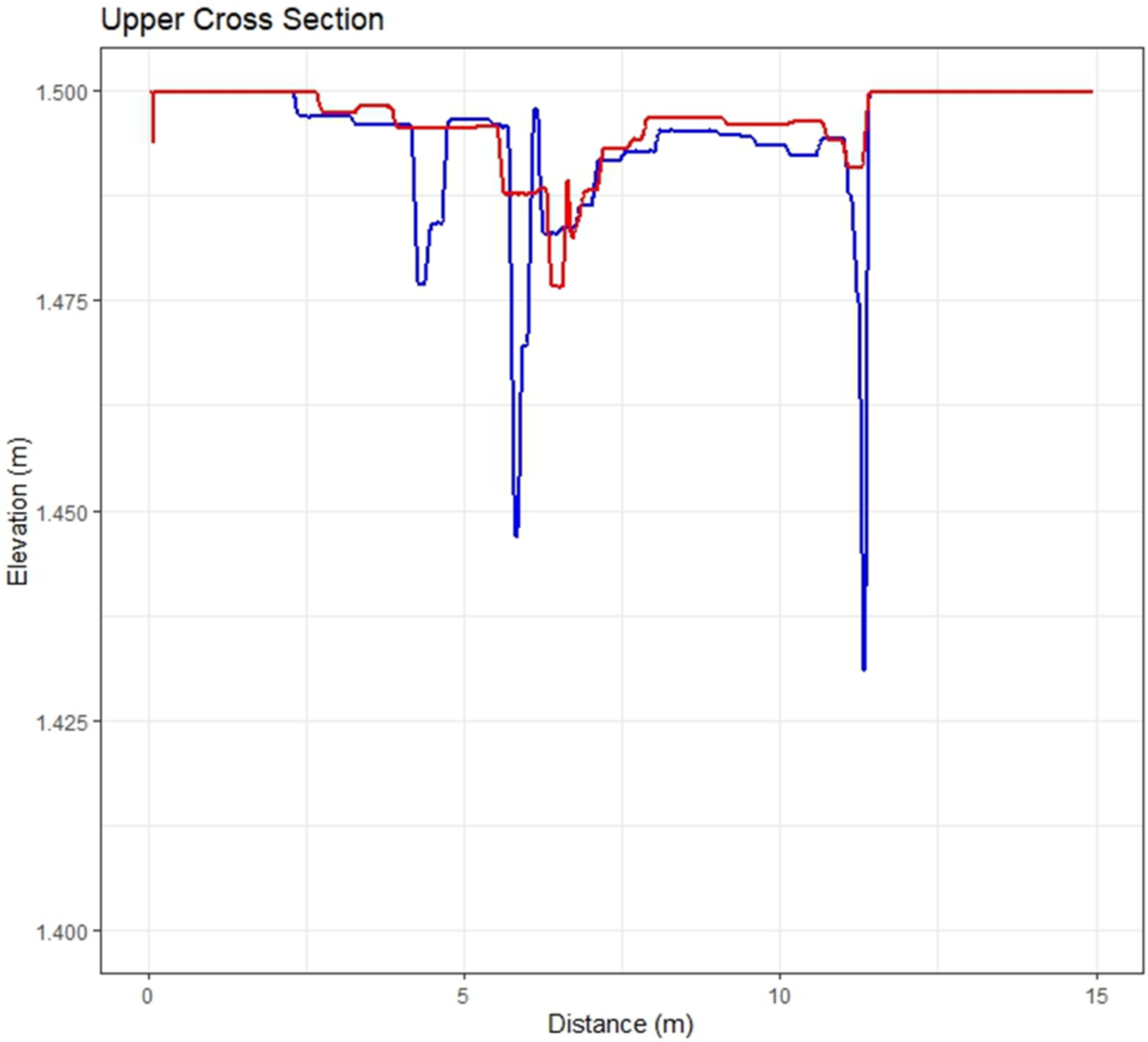

Figure 8 - Visualization for the 2012 and 2023 upper cross section matrix extracts in R. In red is 2012 and in blue is 2023.