Are Low-Altitude Remote Sensing Technologies More Effective Than Traditional Survey Techniques For Monitoring Channel Change?

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Introduction

- In September 2018, the Bloede Dam was removed from the Patapsco River.
- Agencies and researchers are monitoring channel response over time at ~20 of cross-sectional channel transects.
- Although highly precise, transect surveys can be costly, hazardous, and provide little information between transects.
- Structure-from-Motion (SFM) elevation from low-altitude remote sensing is faster, safer, less costly, and can provide continuous estimates of channel form.
- Do continuous estimates produced by remote sensing more effectively capture channel change over large distances?

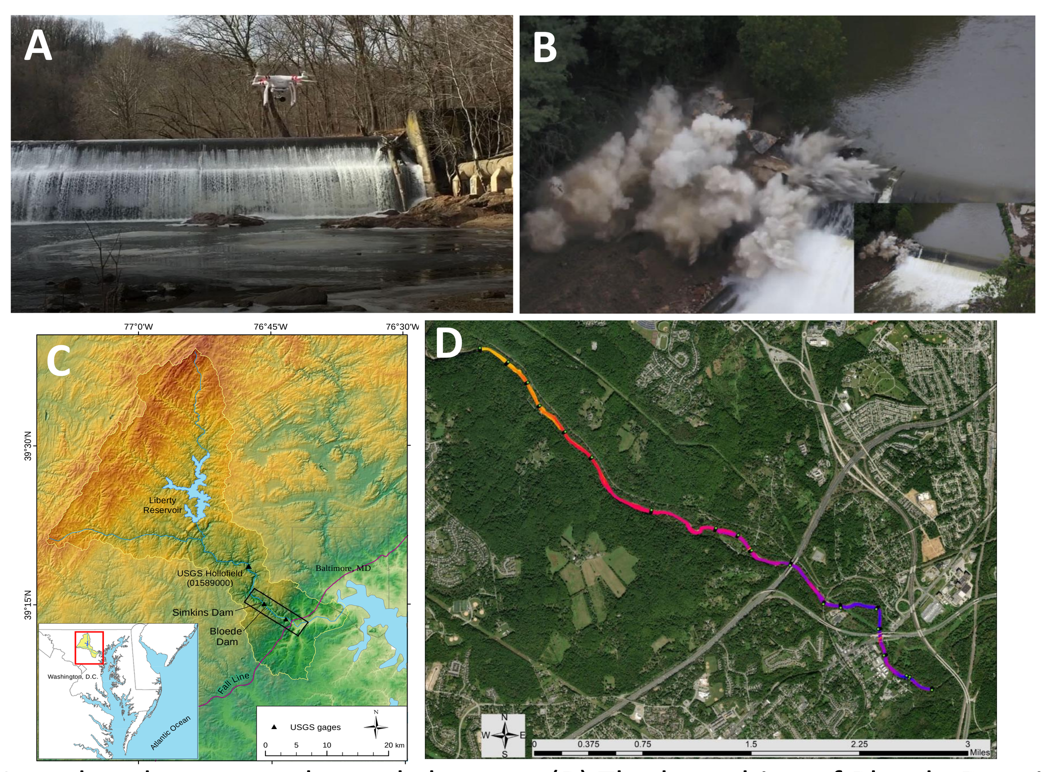

Figure 1. (A) UAV used to document channel changes; (B) The breaching of Bloede Dam in Sept 2018; (C) Study region within the Patapsco River watershed; (D) SFM DEM of the study reach with transect locations.

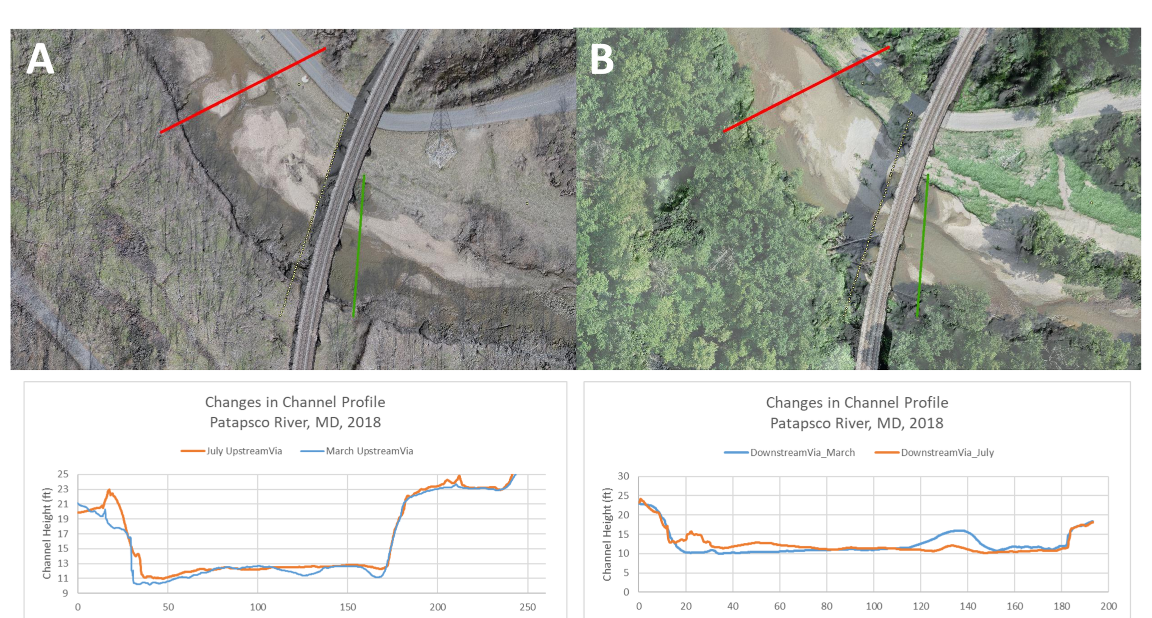

Figure 2. Cross-section comparison before (A) and after (B) the 2018 Ellicott City flood detected with ortho-image reconnaissance showing sub-aerial and bathymetric change that would have been missed by fixed transects.

Problem Statement

- Despite potential to characterize channel changes in between conventional cross-sections, it remains unclear whether benefits from continuous mapping would offset the lack of precision in remote estimation.

Approach

Figure 3. SFM point cloud of the channel at the Thomas viaduct.

- Previous research compared SFM elevation values to surveyed ground truth, producing a mean error of 0.4ft and an RMSE of 1.2ft over 18 cross-sections and 1236 individual observations.
- To assess efficacy of SFM techniques compared to cross-sections, we compared mean error and RMSE of two surfaces interpolated from transects to the SFM channel DEM.

Results

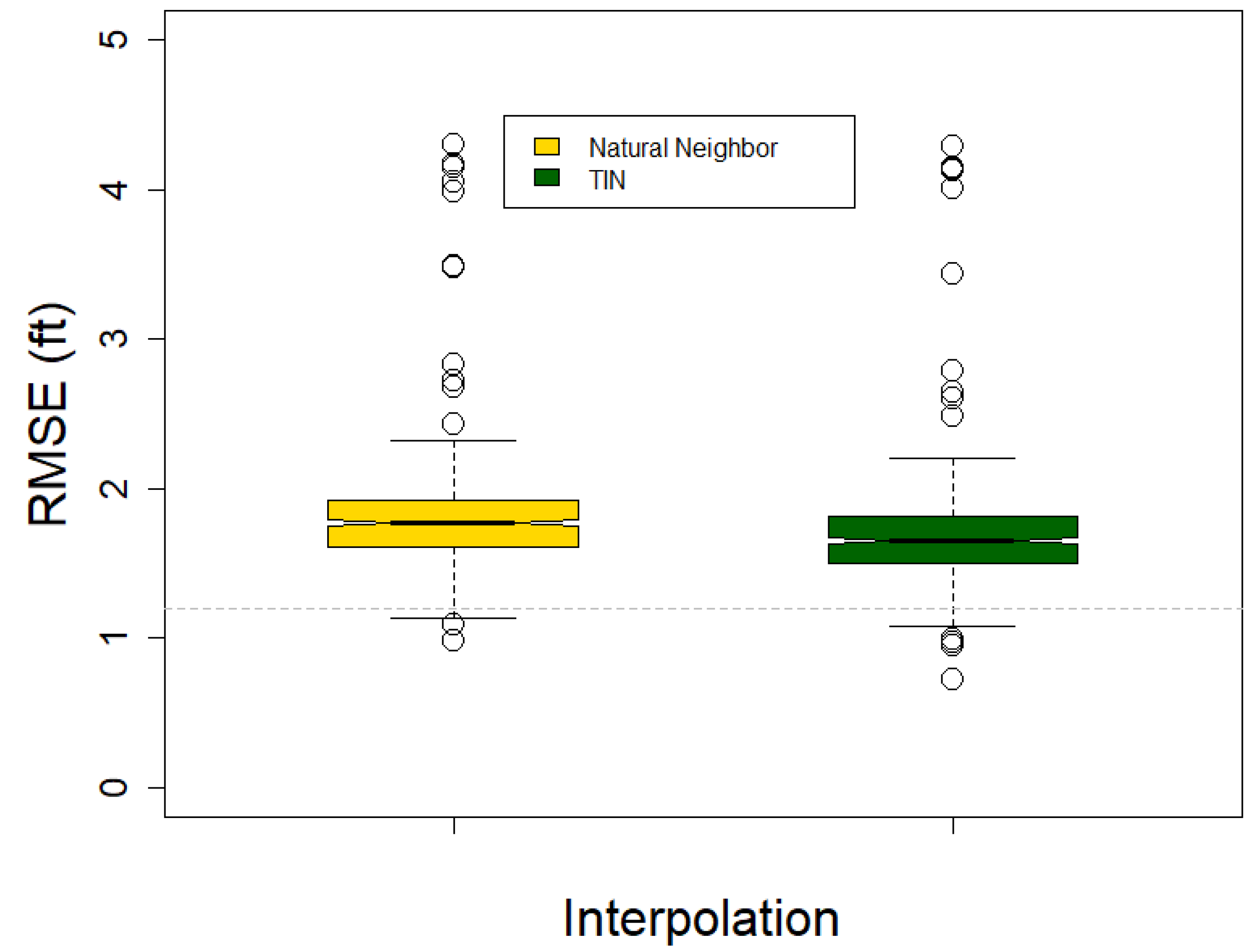

Figure 7. RMSE of mean elevation differences of 500 bootstrap replicates across 20 channel segments. Natural Neighbor Interpolation (yellow) produces an RMSE of 1.80ft, while TIN interpolation (green) produces an RMSE of 1.68ft.

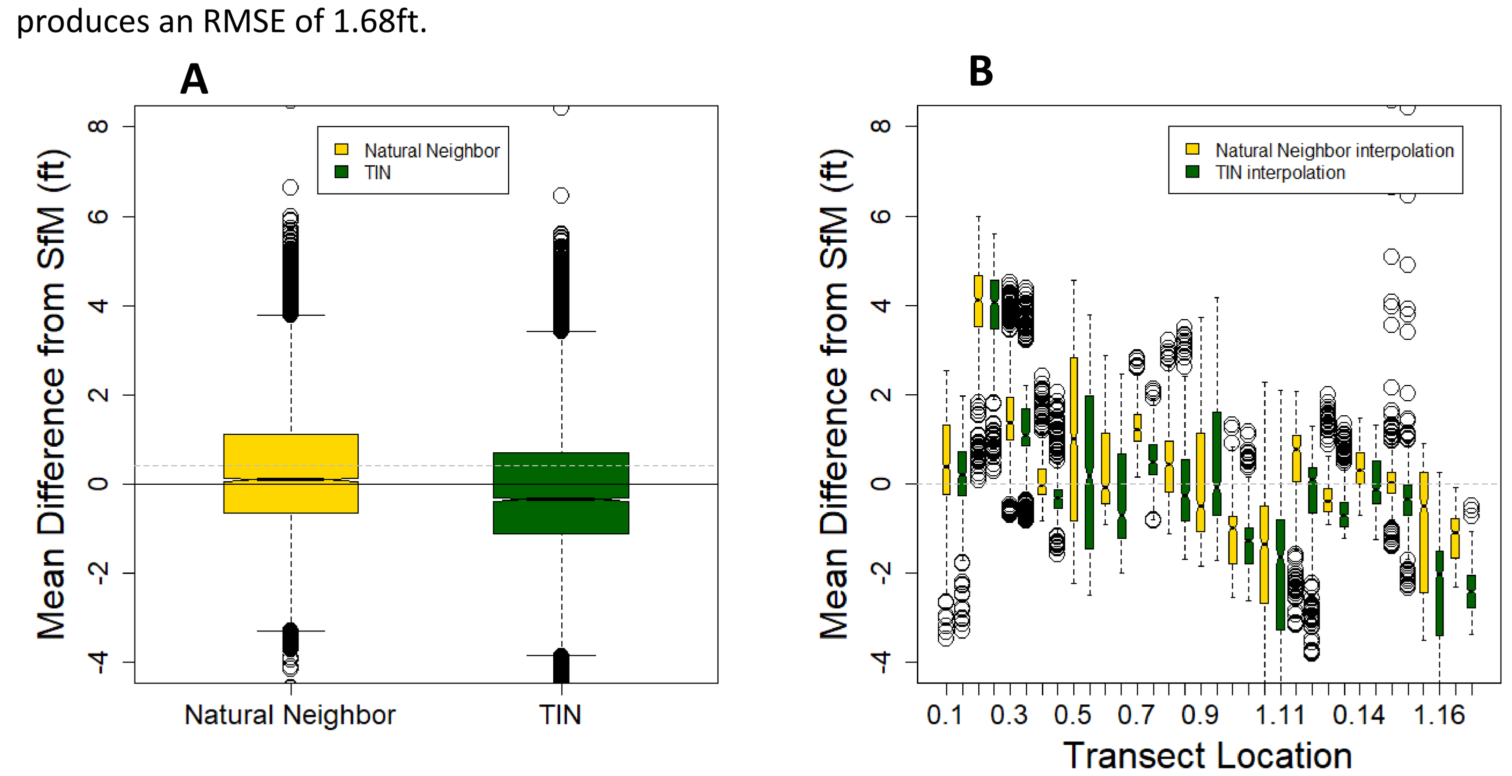

Figure 8. (A) Mean difference from SFM of elevation values. Natural neighbor interpolation (yellow) produces a mean difference of -0.16ft, while TIN interpolation (green) produces a mean difference of 0.30ft. (B) Mean differences from SFM of elevation values by stream segment.

Summary and Conclusions

- Initial exploration indicates SFM from low-altitude remote sensing is substantively more effective at representing channel morphology than interpolation from fixed transects, despite lack of precision.
- Both TIN and NN interpolations resulted in MAEs of <0.5ft and RMSEs of elevation differences <2ft, comparable to the 0.4ft MAE and larger than the 1.2ft RMSE observed comparing SFM elevations to field surveys.
- Our efforts did produce capacity to transform the maps using a channel-centered coordinate system, allowing a more precise comparison.
- However, surfaces created using our channel-centered coordinate system can be further improved using a more precise stream centerline, and this will be the next step in our research.
- Further, recent image acquisition more than six months since the dam removal and again, coincident with field surveys, will allow a robust estimate of both SFM and cross-sections to represent changes through time.

Data Analysis

- A polygon encompassing the stream channel was delineated and used to derive a centerline.
- Distance values from the downstream outlet (s), as well as distance values from the centerline (n) were assigned along cross-sections perpendicular to each centerline pixel.
- These (s,n) coordinates were used to convert both the SFM DEM and the transect points from a Cartesian coordinate system to a stream-centered coordinate system.
- Digital Elevation Models (DEM) were generated from stream-centered transect point data using Natural Neighbor and Triangular-Irregular-Network (TIN) interpolation methods.
- Resampled cross-sections were used to analyze the SFM and interpolated DEMs.
- Bootstrap resampling (500 replicates) was performed within each of 20 channel segments to estimate error across the study reach.
- Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) were calculated from differences between each interpolation and the SFM DEM.

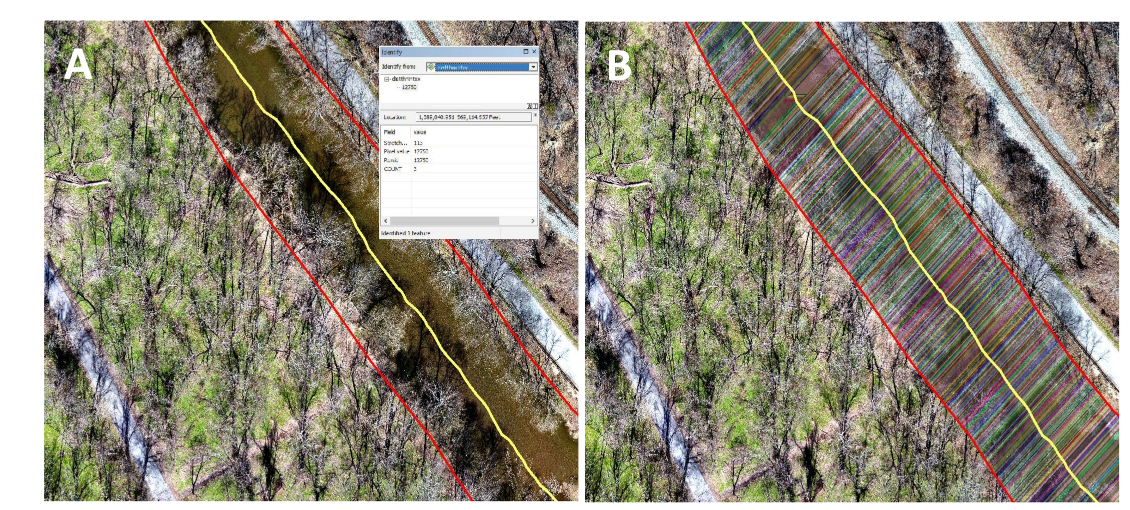

Figure 4. (A) Stream Centerline with associated distance values; (B) Stream Allocation Raster.

Comparing Channel Models from SFM and Interpolation

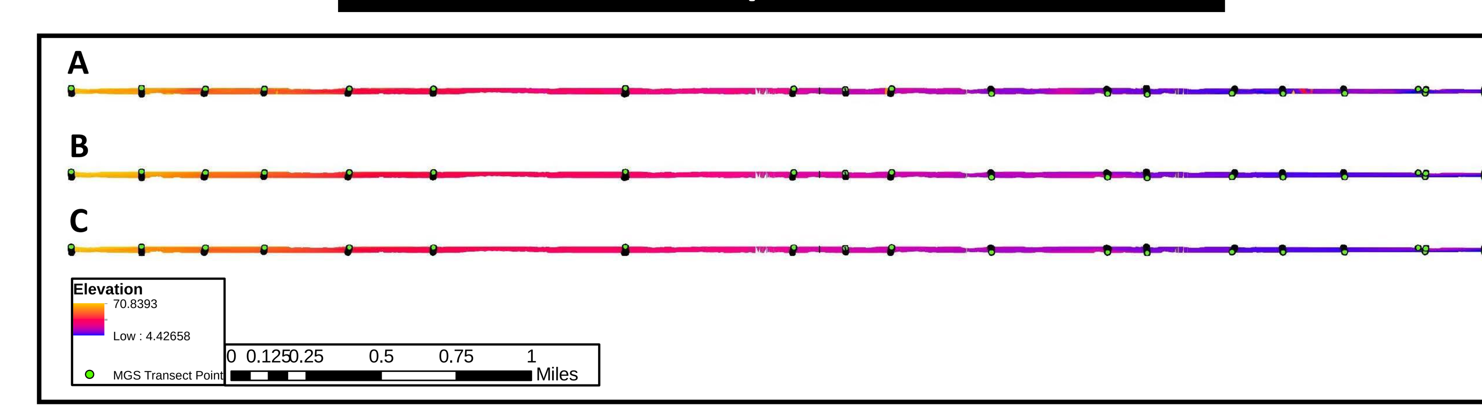

Figure 5. DEMs of the channel within the study region derived from (A) SFM, (B) Natural Neighbor, and (C) TIN interpolation methods.

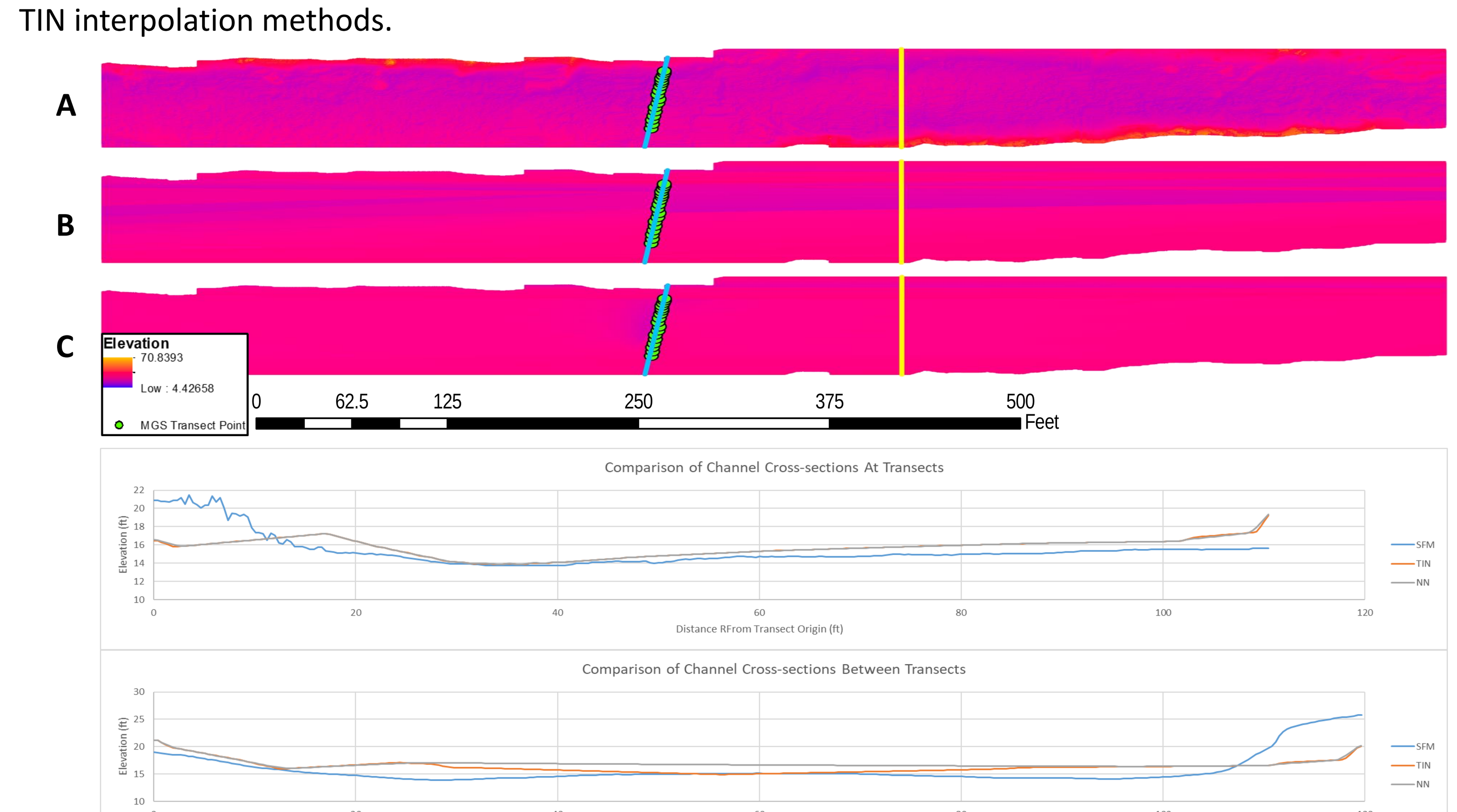

Figure 6. Cross-section comparison at transects (blue) and between transects (yellow) showing how estimated channel form from SFM (A), TIN (B) and (C) NN interpolation were summarized for any cross section.