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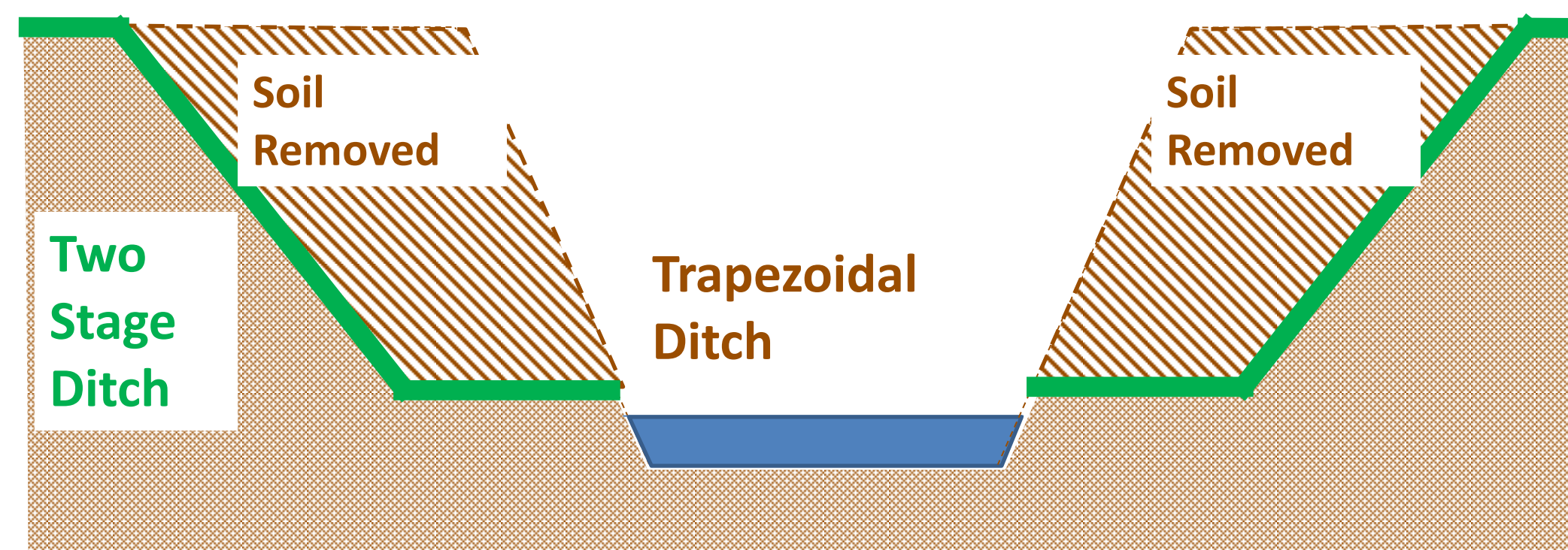
Estimation of Two-Stage Ditch Excavation Volume Using LiDAR Data

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Goal

Importance of Two-Stage Ditches

Drainage ditches are a major pathway for sediment, nutrients, and pesticides to enter stream systems, which threatens environmental and human health (Kallio et al., 2010). Unlike traditional, trapezoidal shaped ditches, two-stage ditches have a vegetated bench that acts as a floodplain for the main channel, which helps to prevent erosion and to increase the processing of nutrients to improve water quality (Kallio et al., 2010.).



Objective

Two-stage ditches are expensive to construct, as they require a significant amount of soil to be excavated. Since ditch geometries vary greatly and since it would be impractical to survey every ditch individually, a modeling tool using computerized data would be of great use to get a rough estimate of how much it would cost to convert a trapezoidal ditch into a two-stage ditch. The objective for this project was to evaluate the potential of Light Detection and Ranging (LiDAR) (Indiana Geographic Information Council, 2012) data to create an estimate of the excavation volume of a two-stage ditch by comparing the excavation volume obtained by LiDAR with that obtained by surveying with a Real Time Kinematic Global Positioning System (RTK GPS) unit.

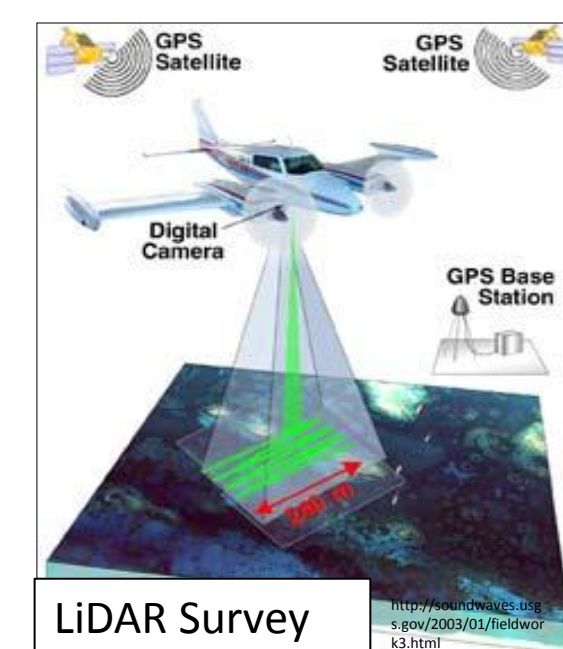
RTK GPS v. LiDAR

RTK GPS

- Used in combination with a GPS satellite linked stationary base or wireless network
- Must be collected by hand for high level accuracy (≤ 5 cm)

LiDAR

- Bounces light waves of the ground to determine elevation
- Can be collected by plane, but is less accurate than RTK GPS (≥ 15 cm) (Steinmetz, 2013)
- Is available online for most counties in the state of Indiana



Methods

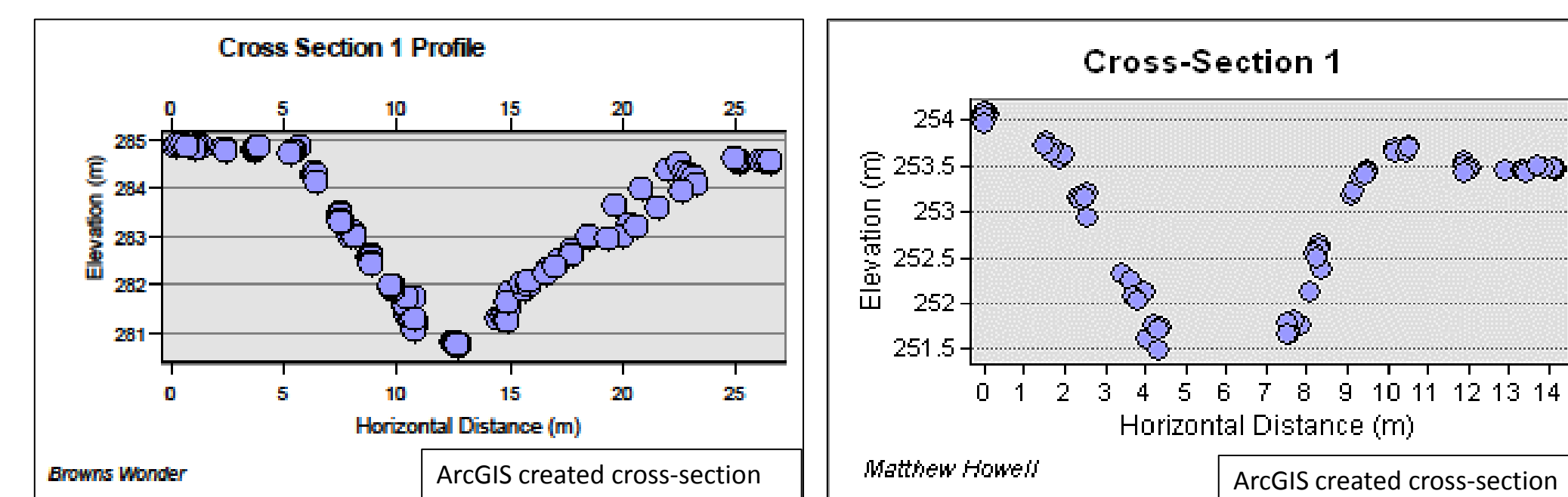
RTK GPS Surveying

- Surveyed 2 ditches, Matthew Howell (Howard Co., IN) and Brown's Wonder (Boone Co., IN)
- Collected 4 cross-sections per ditch
- Each cross-section represents a stable bank formation that is constant for 2 m to either side to ensure that the bank had not significantly changed since the LiDAR data was taken in 2011
- ≥ 10 m between cross-sections



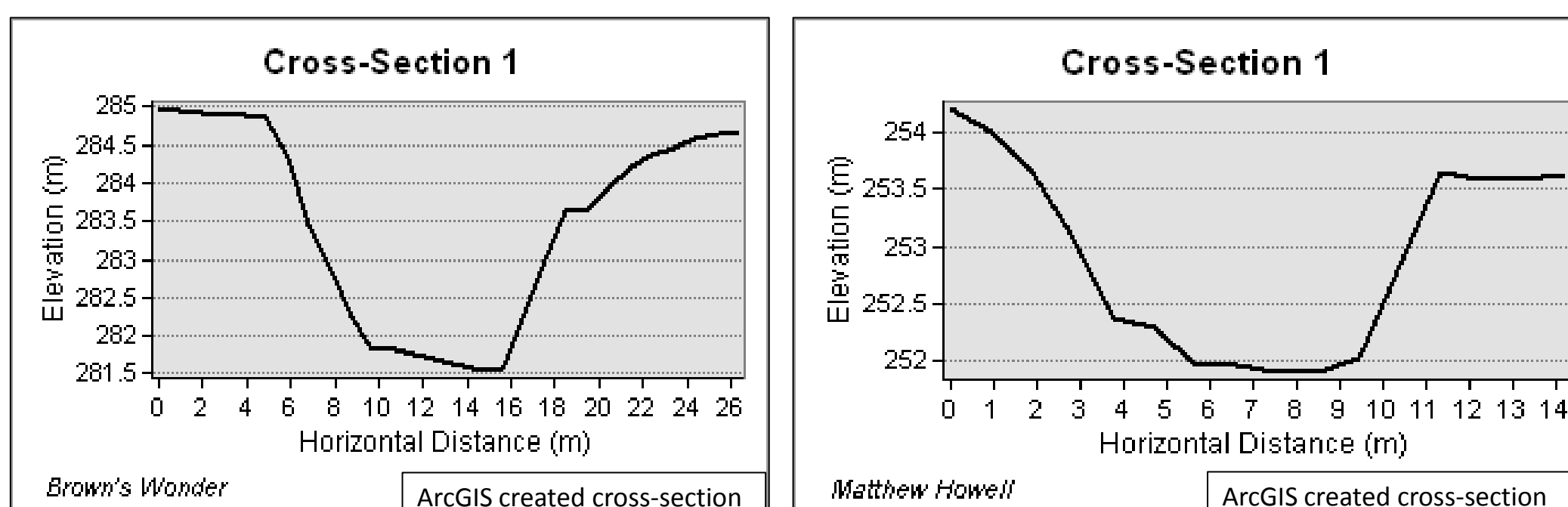
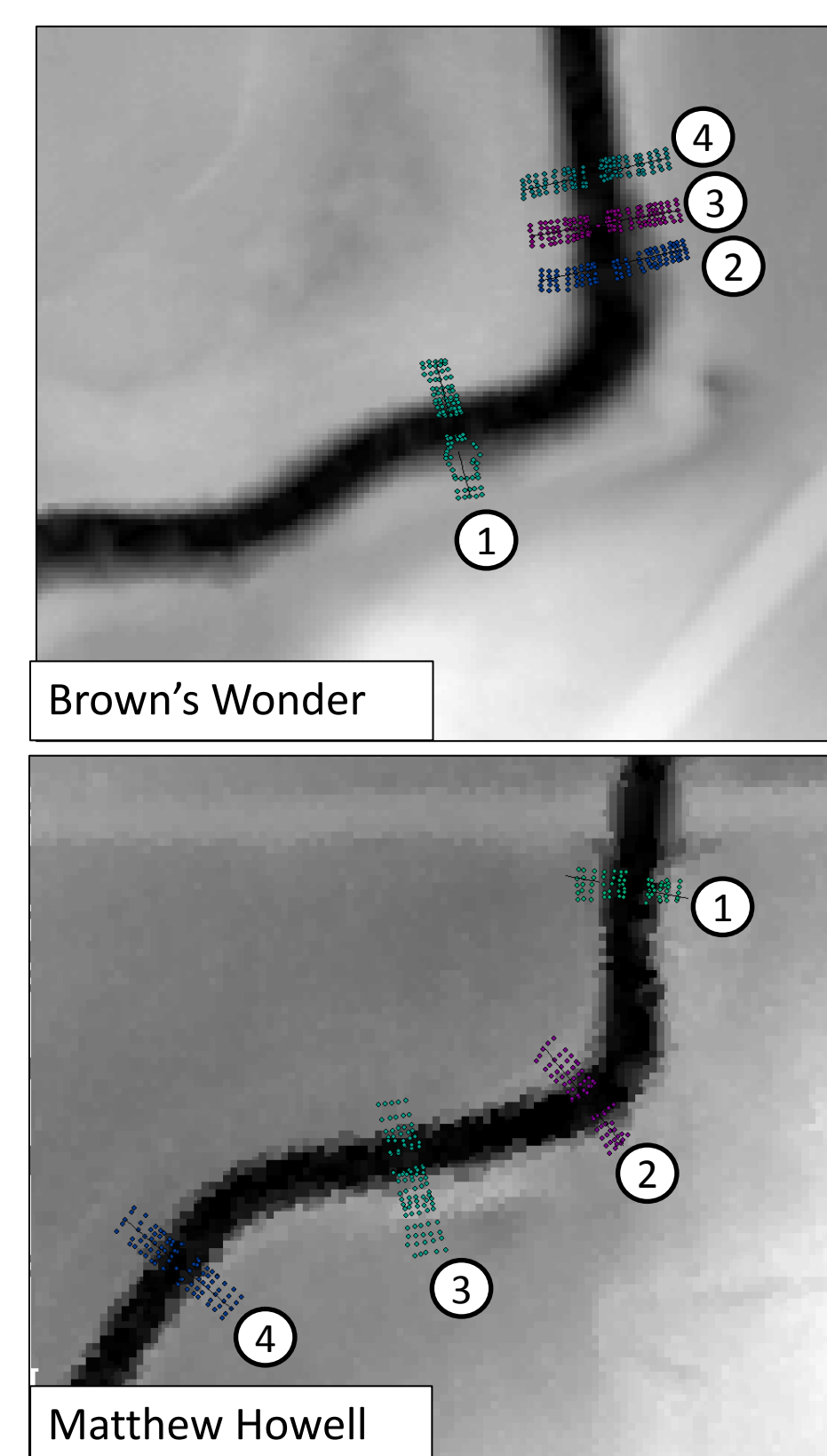
RTK GPS Analysis

- Obtained cross-section profiles in ArcGIS using 3D Analyst Point Profile tool



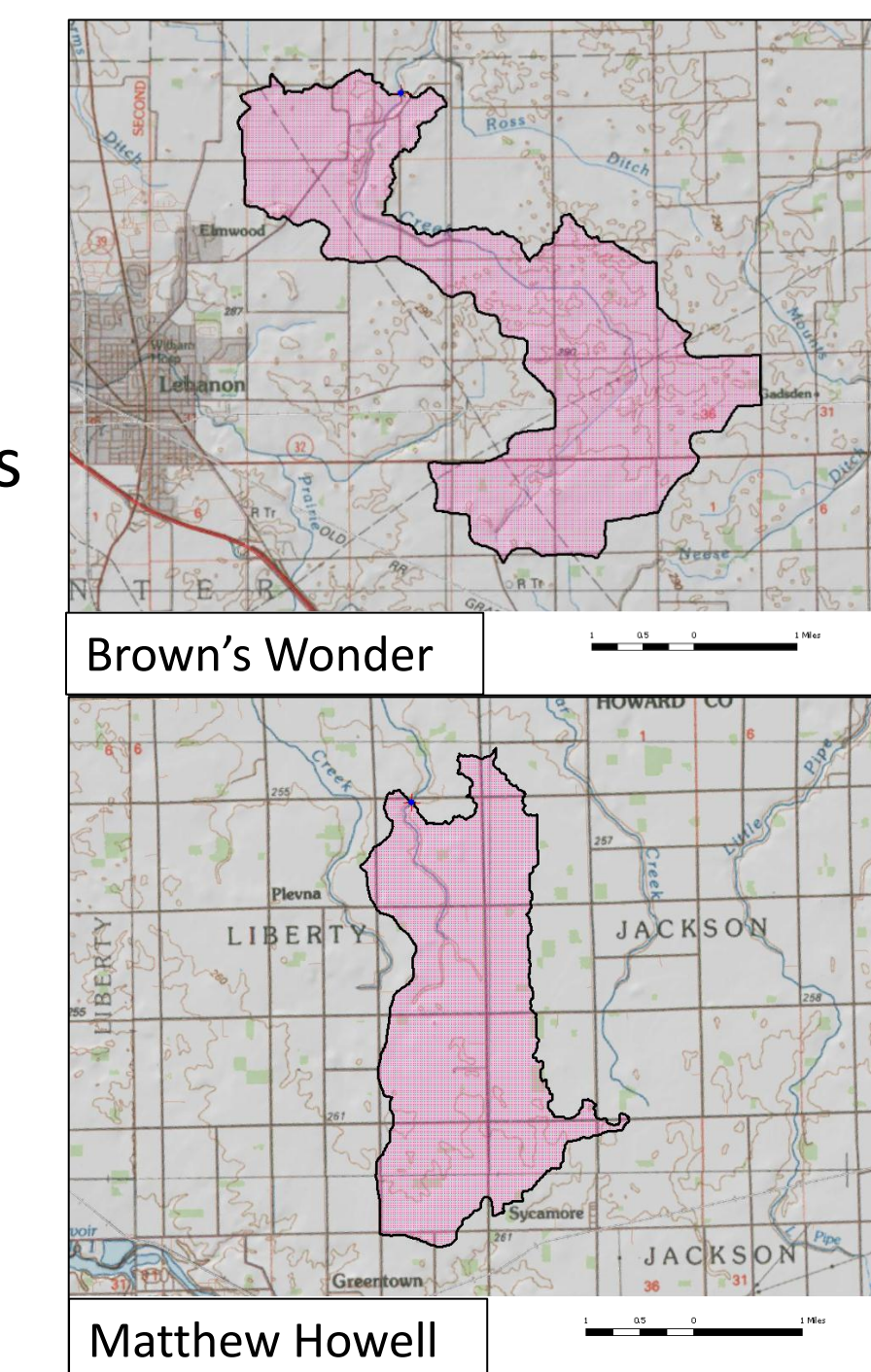
LiDAR DEM Analysis

- Downloaded LiDAR derived DEM (Digital Elevation Model) from OpenTopography by filtering ground points
- Obtained profiles in ArcGIS using 3D Analyst Profile Graph tool
- Cross-sections taken at same place where cross-sections were taken during RTK GPS survey

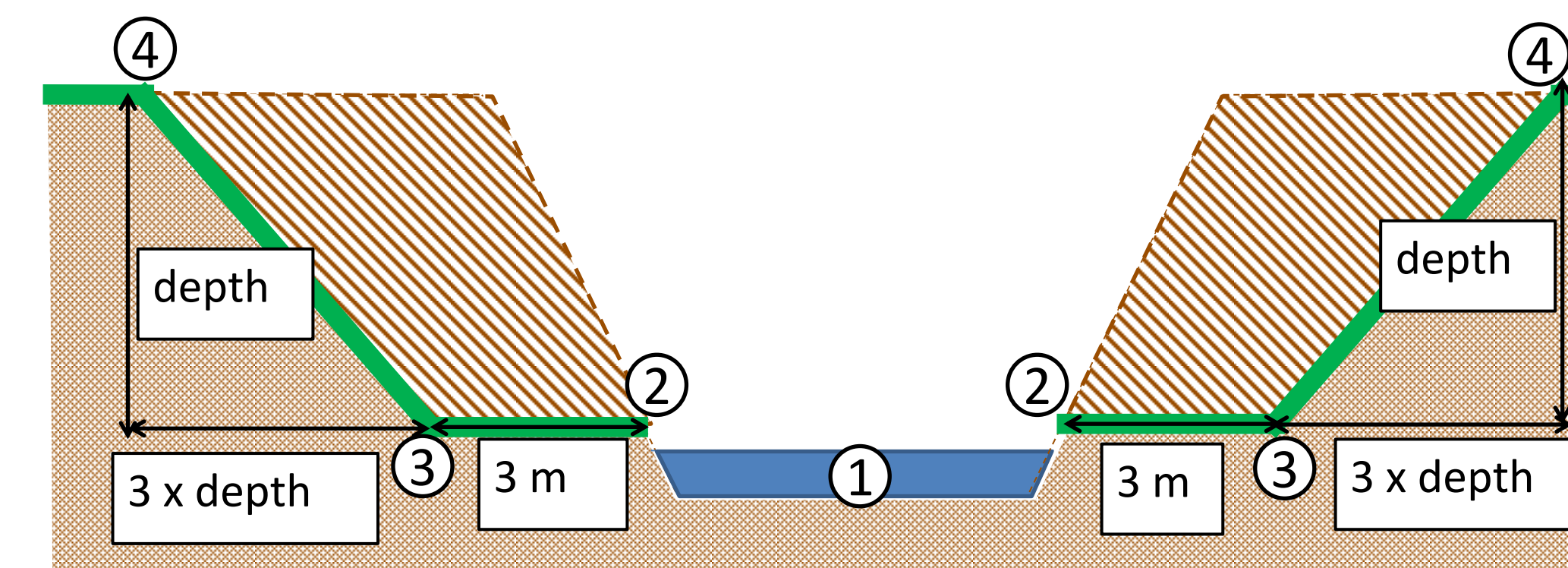


Watershed Area Calculation

- Calculated watershed areas from most downstream point of area surveyed using USGS StreamStats program
- Used published regional curves for Central Till Plain Region of IN to obtain mean bankfull depth (Robinson, 2013)



Two-Stage Ditch Calculation



Hypothetical Two-Stage Points:

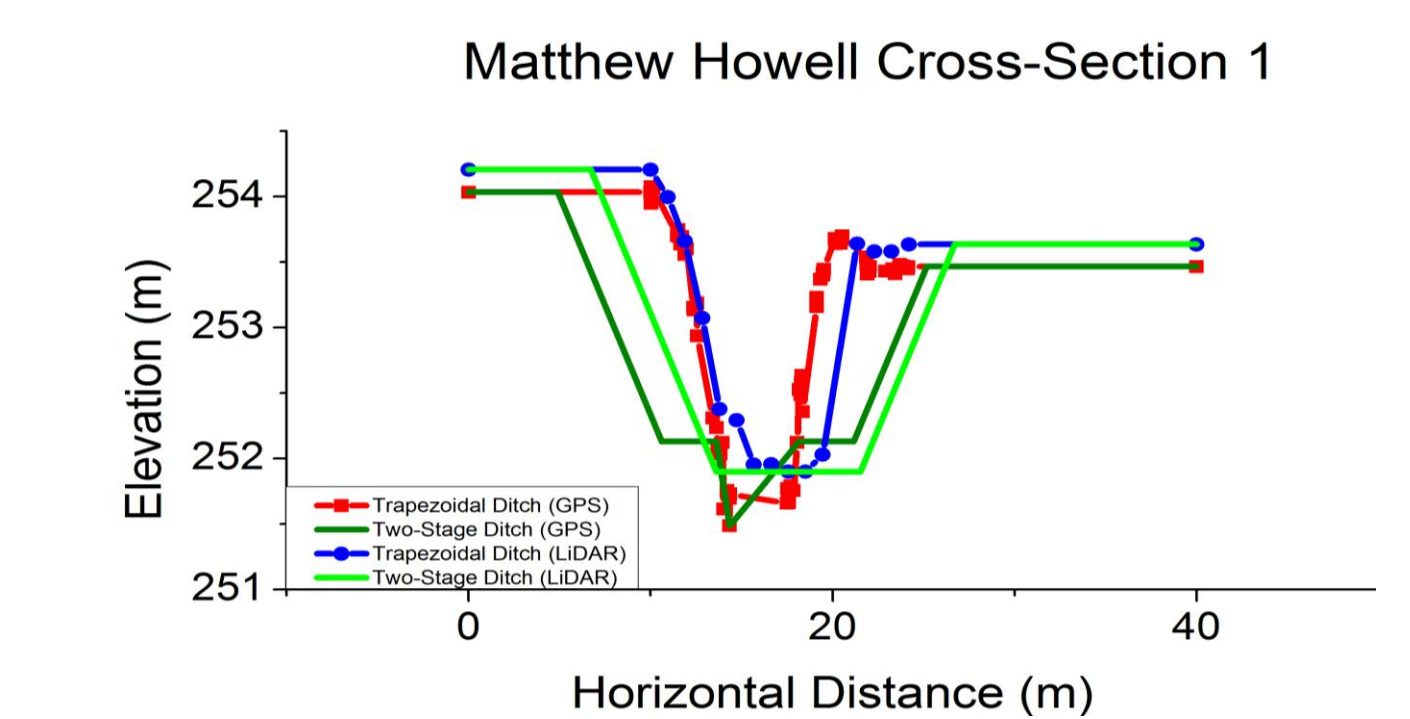
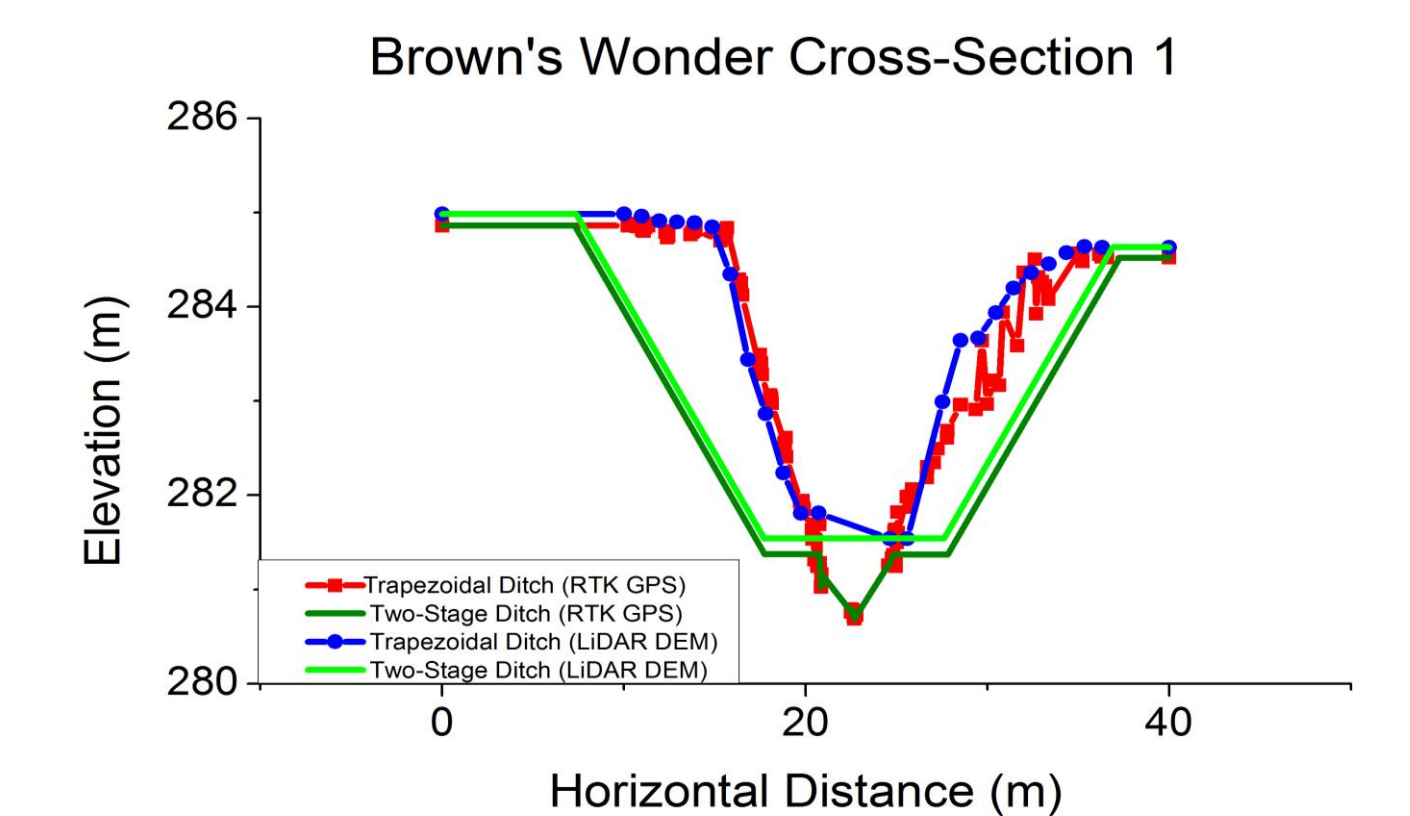
- Lowest Point:** The bottom of the channel for RTK GPS, or the water surface for LiDAR derived DEM
- Bench Height:** The calculated mean bankfull depth (see Watershed Area Calculation) plus the lowest point's elevation (1) for RTK GPS, or simply assume the lowest point's elevation for LiDAR derived DEM (1) is equivalent to the bench height
- Before Slope:** The same elevation as the bench height (2), but 3 m away horizontally
- After Slope:** horizontal distance= 3 x (highest elevation-bench height), elevation= highest elevation (USDA & NRCS, 2001)

Excavation Volume Calculation

- Difference in area under trapezoidal ditch and two-stage ditch calculated with OriginPro
- Distance between cross-sections measured using ArcGIS
- Length of cross-section=0.5*Distance to cross-section on the left+0.5*Distance to cross-section on the right
- Volume/m of ditch=Sum(Length of cross-section*Area)/Sum(Length of cross-sections)

Results

Ditch Name	Watershed Area (mi ²)	RTK GPS Based Volume (m ³ /m)	LiDAR DEM Based Volume (m ³ /m)	% Difference
Brown's Wonder	8.556	26.50	22.02	16.91
Matthew Howell	5.666	41.22	31.96	22.47



Conclusion

Since the LiDAR method does not penetrate under water, the elevation of the bottom of the ditch is unknown. This makes it difficult to accurately calculate the bench height, which is why this project assumed that the bench height and LiDAR derived DEM water level were approximately equal. While this approximation worked for Brown's Wonder, the LiDAR derived DEM water level for Matthew Howell was clearly lower than the bench height, leading to a more significant difference in the excavation volume estimate. For the ditches measured, the average difference in estimated excavation volume between LiDAR derived DEM and RTK GPS analysis was 19.69%, suggesting that the method has potential for providing a first draft of costs without time-consuming surveys, but more ditches need to be surveyed to see if differences in the water surface and the bench height are a persistent problem.

Acknowledgements

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