Low-Cost Aerial Mapping:
Opportunities and Pitfalls

Luke Javernick, Ph.D.

Aerial Mapping

Situation: Your project needs aerial imagery and current topo/elevation

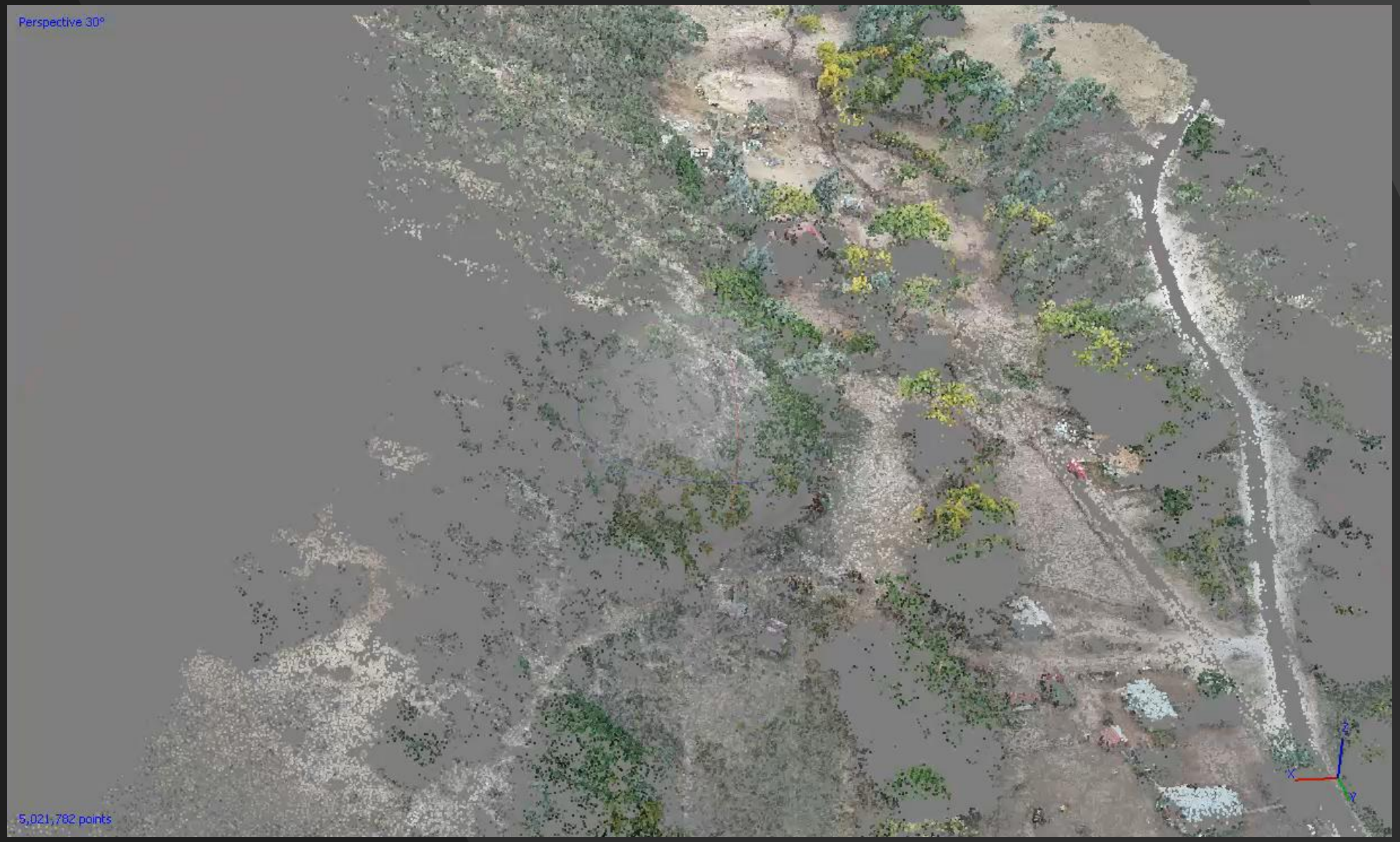
Opportunities:

- It doesn’t have to be expensive
- Great accuracy and resolution
- Fast turnaround

Challenges:

- A lot of potential pitfalls
- Mistakes and errors propagate/cumulative

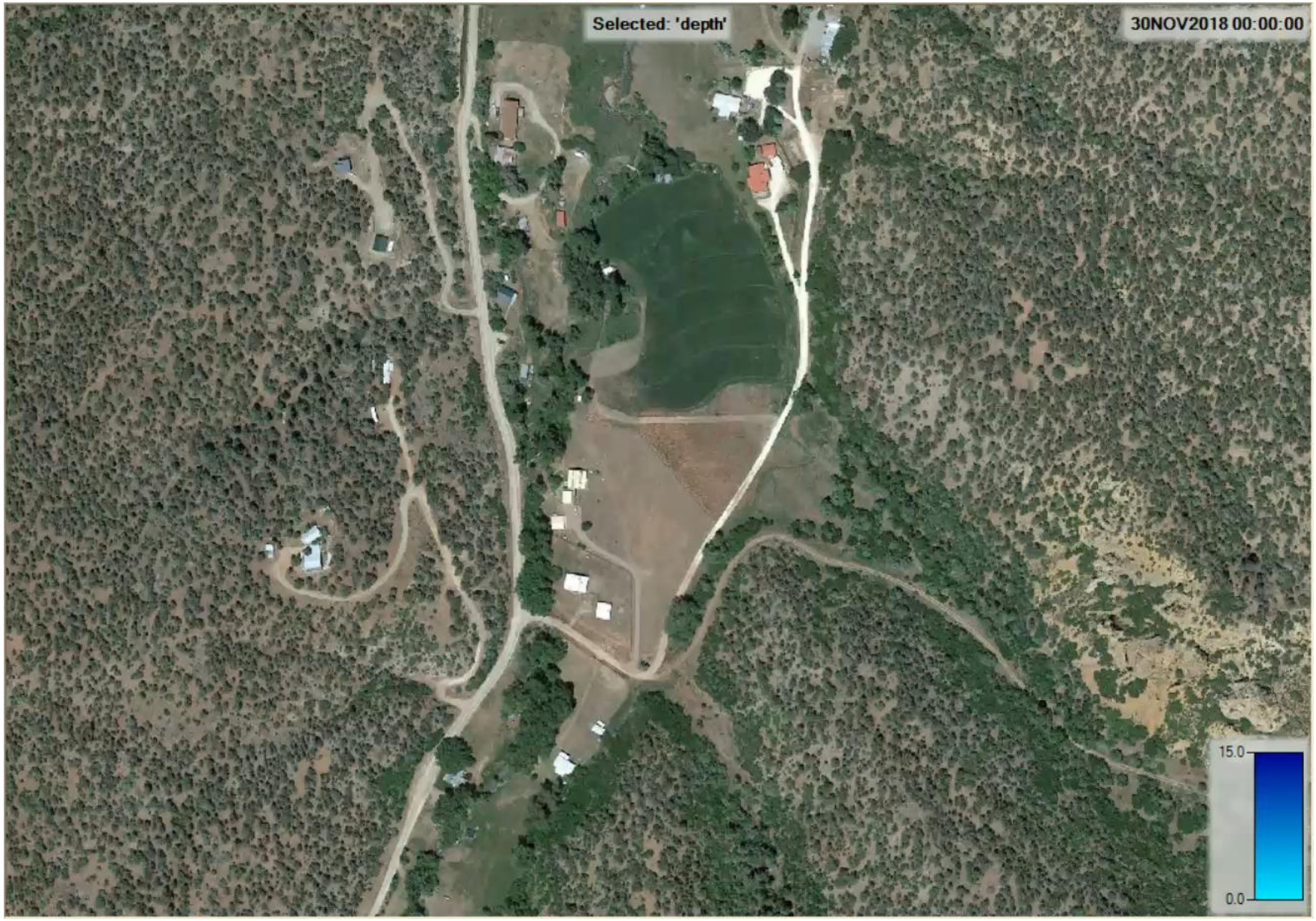
Example: Elevation Model and Orthoimage



DEM

- 0.5 billion points
- Accuracy 0.04 ft
- Precision 0.27 ft

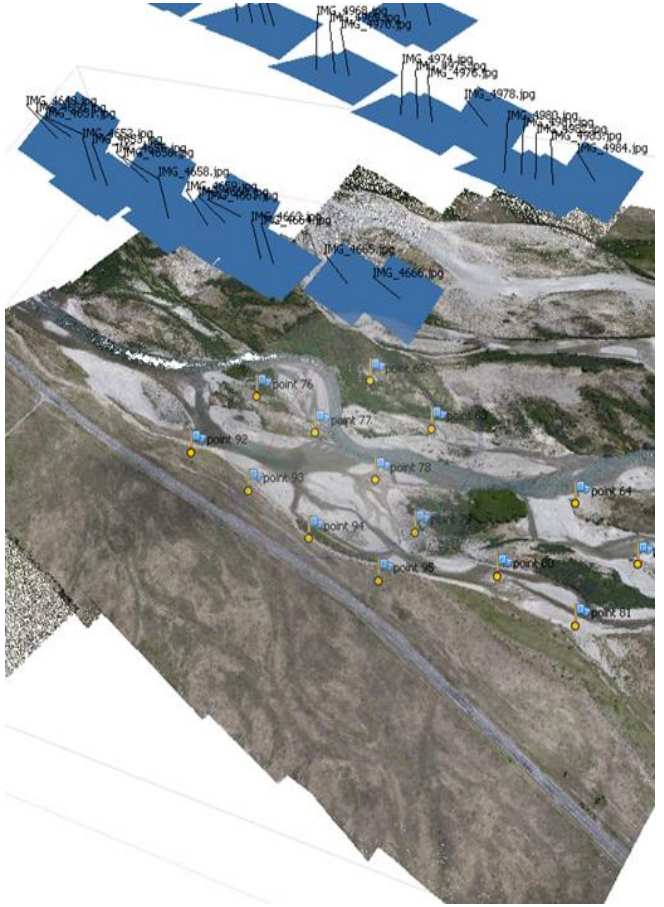
HYDRAULIC MODEL



Mapping: 3 Main Phases

1: Ground Data (Survey)

2: Image Acquisition



3: Data Processing

2011 – Present

Millimeter to Square Miles

DEM: z errors 0.002 m

(0.078 inches)

DEM: z errors 0.04 m

(1.57 inches)

DEM: z errors 0.10 m

(4.1 inch)

Pitfalls: Lessons Learned

Science **AND** Art

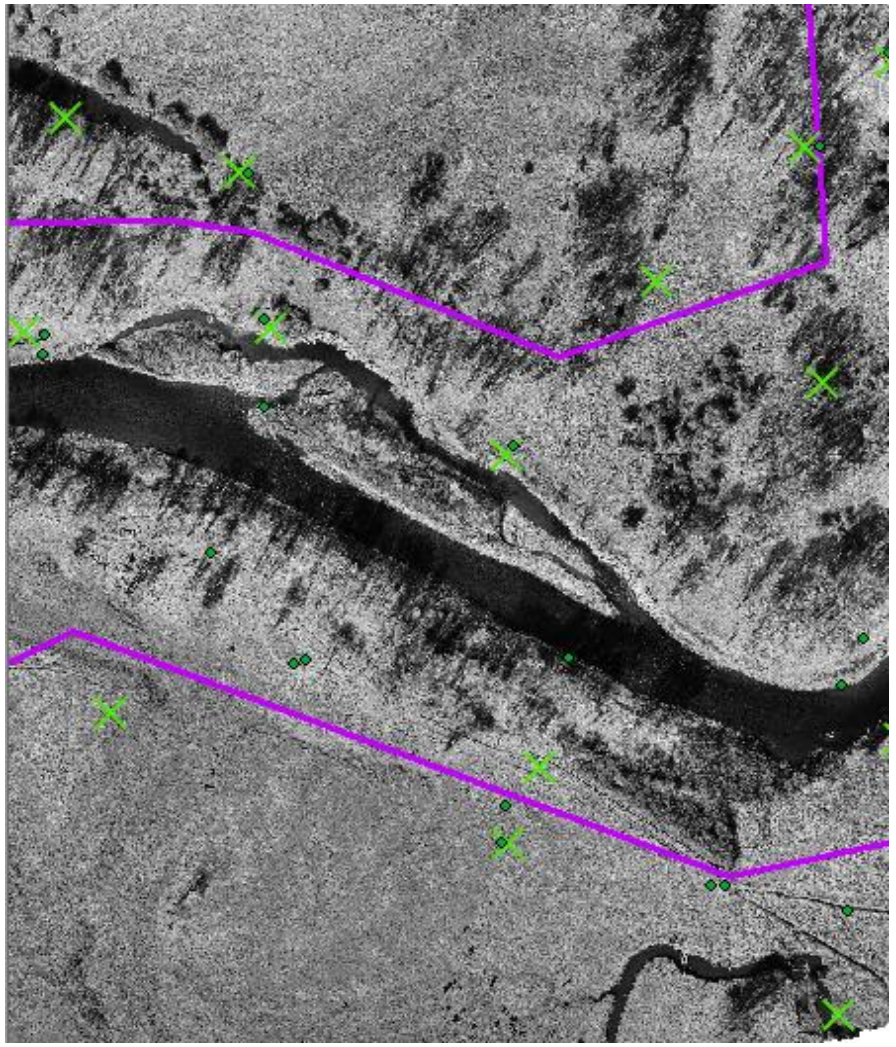
- Science
  - Land Survey
  - Photogrammetry, Structure-from-Motion (SfM)
  - Aircraft/drone operations and data collection (remote sensing)
  - Data processing, GIS, statistics
- Art
  - Photography

Keys to Success

- High quality imagery
- Redundant and accurate ground survey
- Processing: Know your software, control your software.

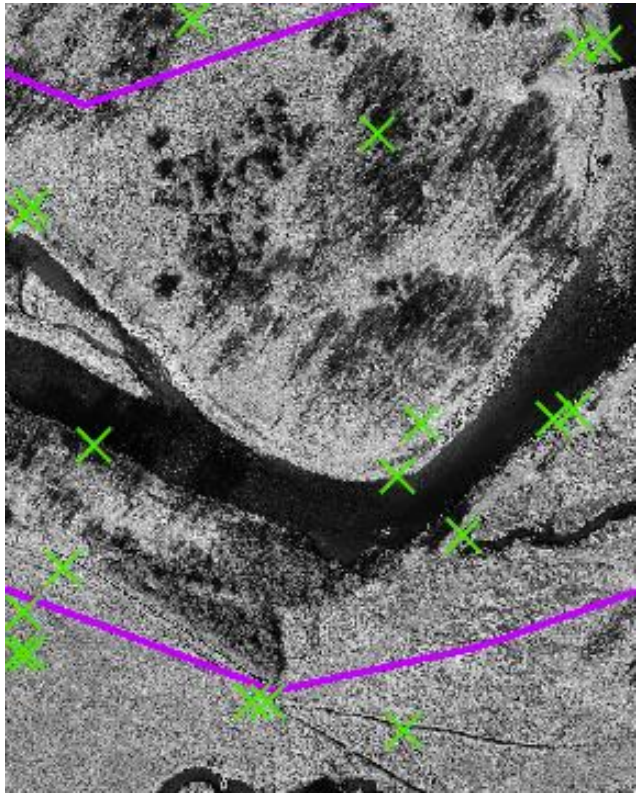
Ground Survey

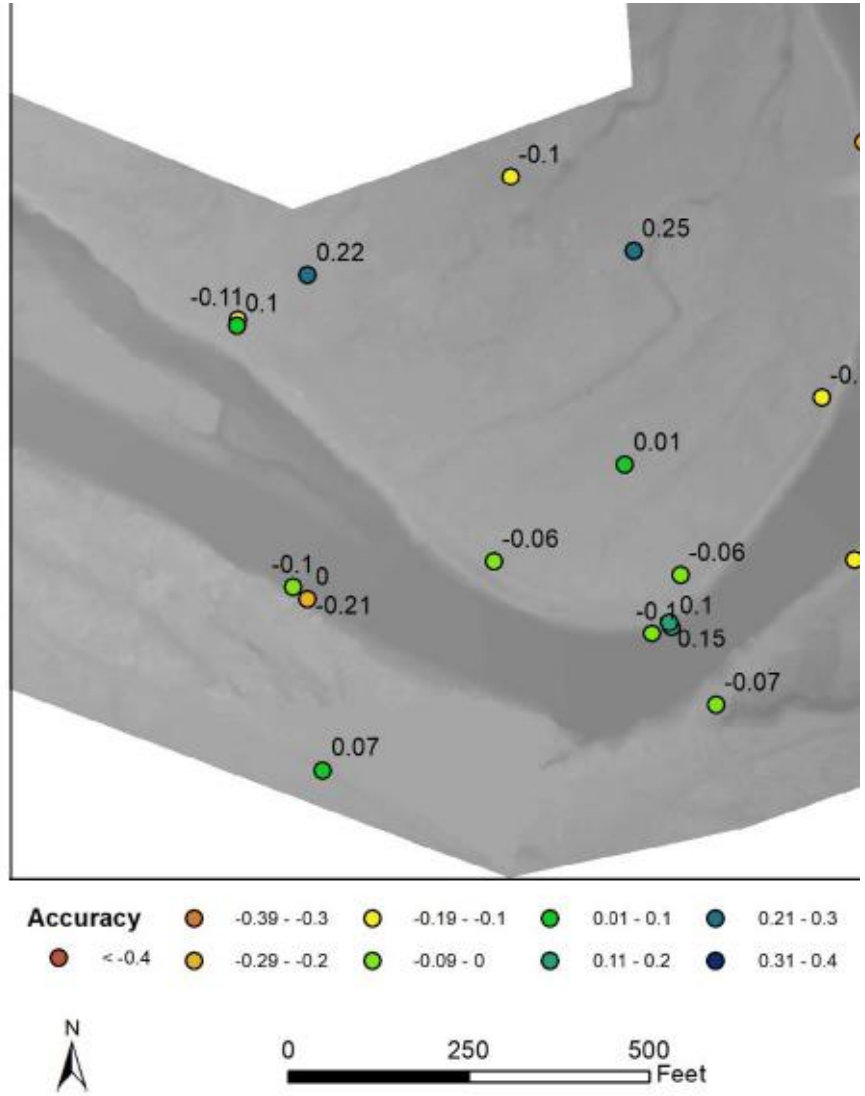
- Your survey and imagery need to support your accuracy goals.
- Ground Control Points (GCPs) need to be inside and just outside of your area of interest
- More, more, and more GCPs than you think you need.



Ground Survey

- Survey your GCP and then do another survey point by it for redundancy.
- Collect random ground survey points (ground truthing)





Ground Survey: Considerations

GCP vs natural control objects

- **GCPs**
  - Professional targets are:
    - Expensive, or time consuming to make
    - Labor intensive to place and remove (2 days for placement and removal)
  - Painted targets are accurate, affordable, and last several weeks to months (depending on paint used).
- **Natural targets are:**
  - Less accurate
  - Hard to find in images
  - Depending on when you find them, they could be different location than in images

Imagery

- Calculate Ground Sample Distance
  - Resolution constrains your overall accuracy
  - See your GCPs: width = 2 pixels
- Shutter speed: Avoid blur
- Combo ISO and Aperture for lighting
- 6 pictures covering each area mapped

- Challenges:
  - 70-80% image overlap. Difficult in airplane.
  - Camera vibration = blur, focus slipping
  - Shadows and snow
  - Vegetation: if you want to model the bare earth, you need to try and see it in 3 places.

Processing

- Parabolic errors
  - Redundancy pays off – double check your survey
  - Check each GCP and make sure the centroid is marked in each picture
- Avoid automatically processed data and software
- Gradual Selection – reduce the errors

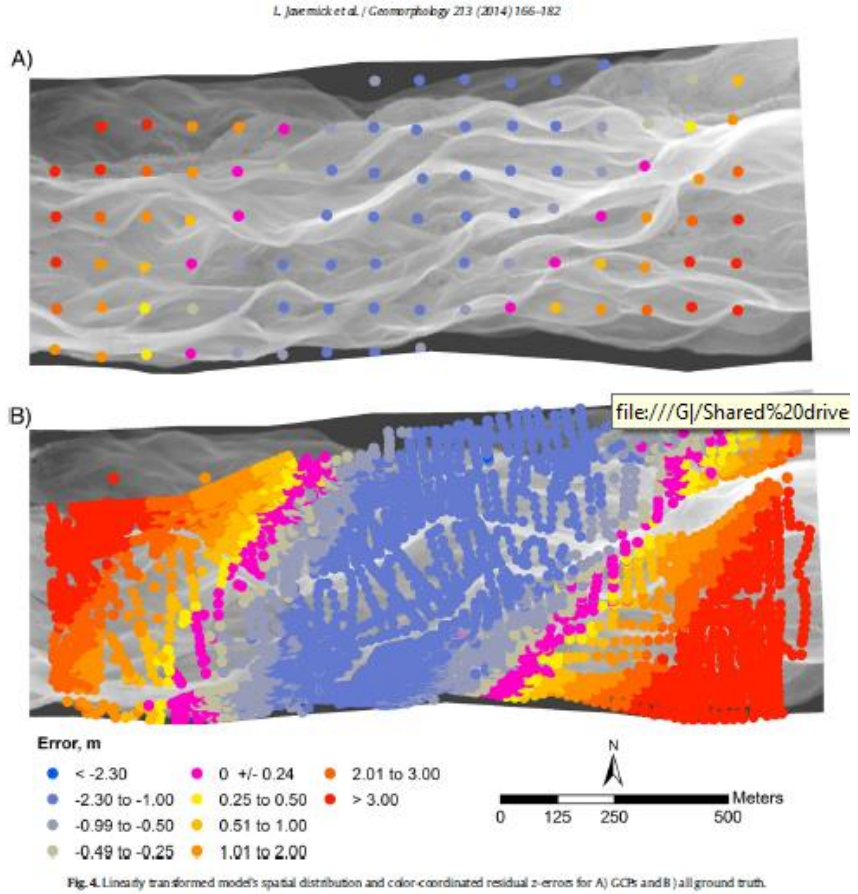
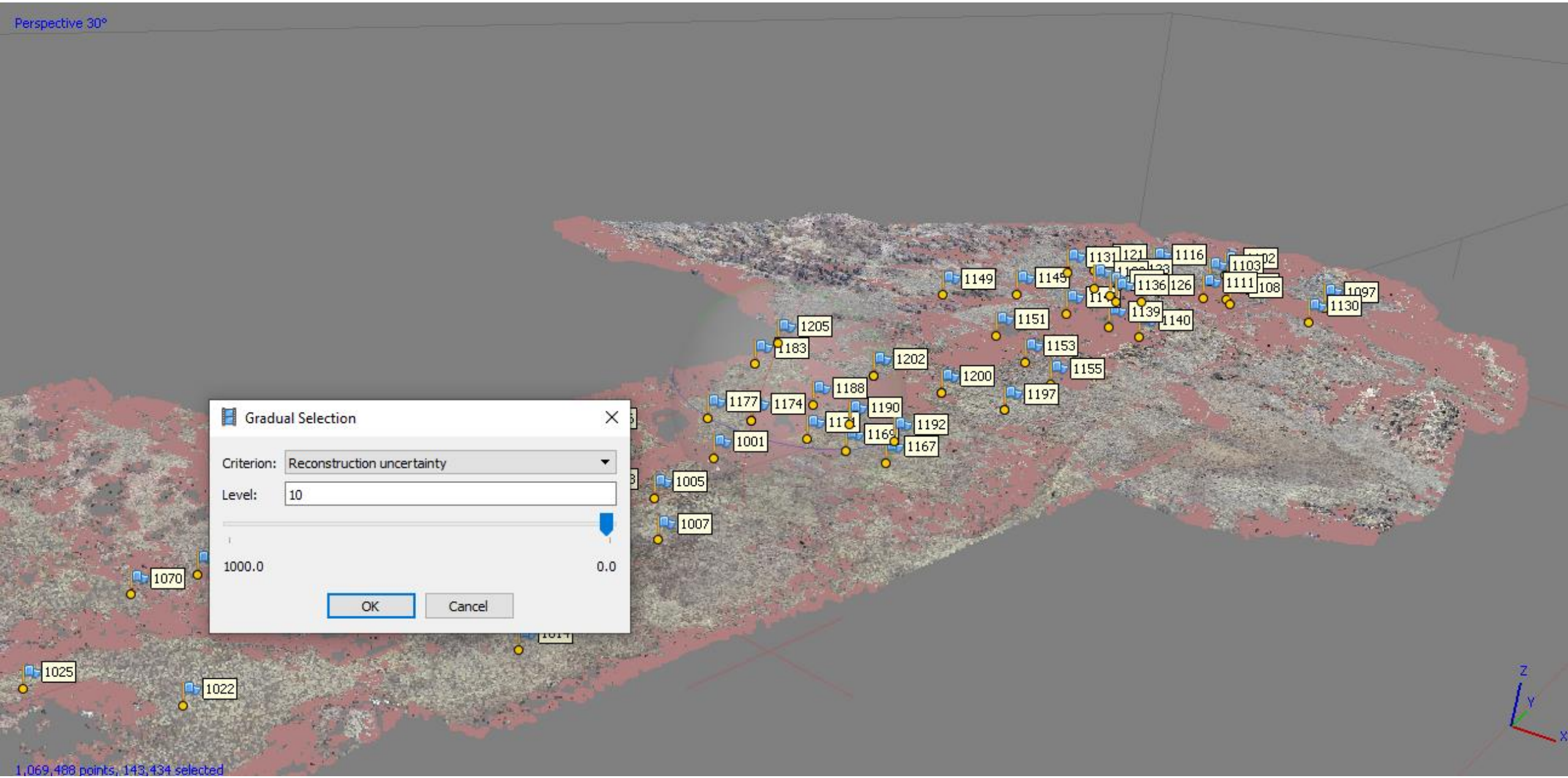


Fig. 4. Linearly transformed model's spatial distribution and color-coordinated residual z-errors for A) GCPs and B) all ground truth.


Perspective 30°
Gradual Selection
Criterion: Reconstruction uncertainty
Level: 10
1000.0
0.0
OK
Cancel
1,069,488 points, 143,434 selected

Processing: Challenges

Computer processing

- Powerful desktop with powerful graphics card

Bathymetry.

- It can do shallow water if clear, but accuracy diminishes with depth.
  - Dietrich, 2016,
- You can combine the SfM (shoreline points for WSE) with optical bathymetric mapping.
- You can take surveys transects or hydrographic surveys.

Vegetation

- Filter the point cloud with zmin elevations (ToPCAT)
- Filter the points by color
- Whitebox Remove Off Terrain Objects (OTO)
- Survey under the vegetation

Video

- Film does not work well.

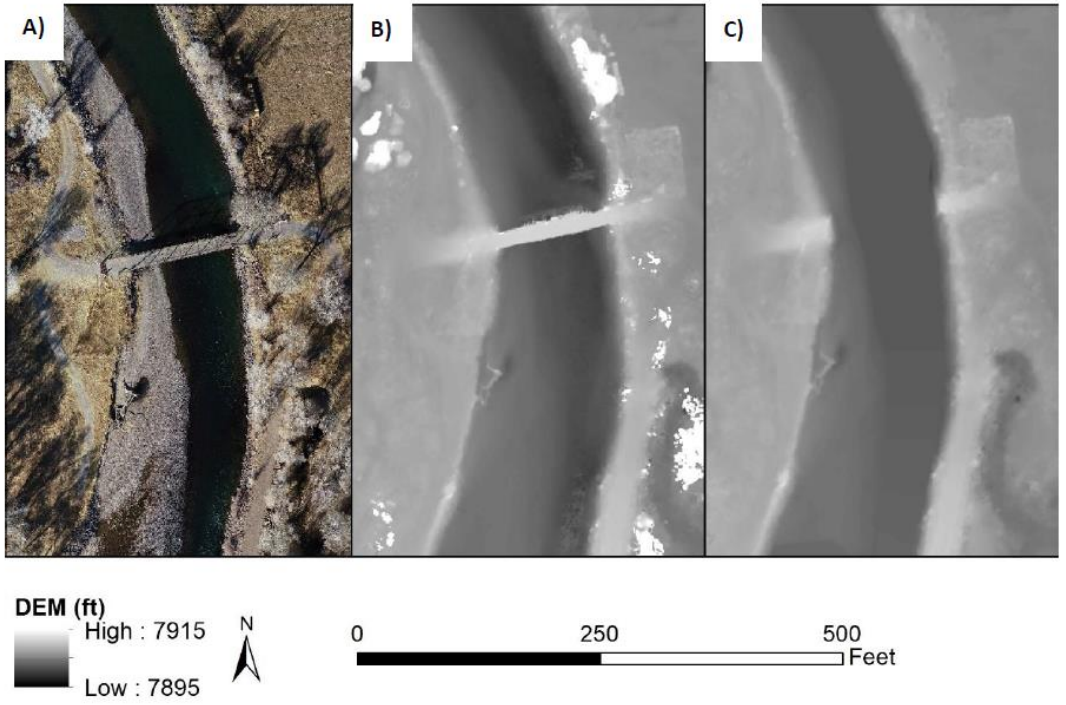


Figure 1: Examples of the generated: A) orthoimagery, B) digital surface model (DSM) (i.e. vegetation included), and C) bare earth digital elevation model (DEM) (all at 1 foot resolution).

Dietrich, 2016. Bathymetric Structure from Motion: Extracting shallow stream bathymetry from mulit0view stereo photogrammetry. Earth Surface Processes and Landforms.

Pitfalls: Lessons Learned

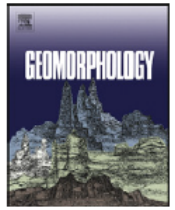
In a nutshell:

- Accuracy – you can't outperform your image resolution or your survey accuracy.
- Collect imagery with higher resolution than your accuracy requires
- Include redundancies in your survey
- Collect more GCPs than you think and outside your area of interest
- Process your data knowing the tradeoffs between quality and processing time.
- Know your software for best results

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph



Modeling the topography of shallow braided rivers using Structure-from-Motion photogrammetry

L. Javernick [a,*], J. Brasington [b], B. Caruso [a]

Contents lists available at ScienceDirect

Advances in Water Resources

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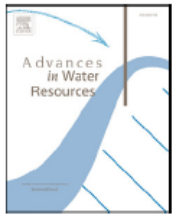


Evaluation of a numerical model's ability to predict bed load transport observed in braided river experiments

Luke Javernick*, Marco Redolfi, Walter Bertoldi

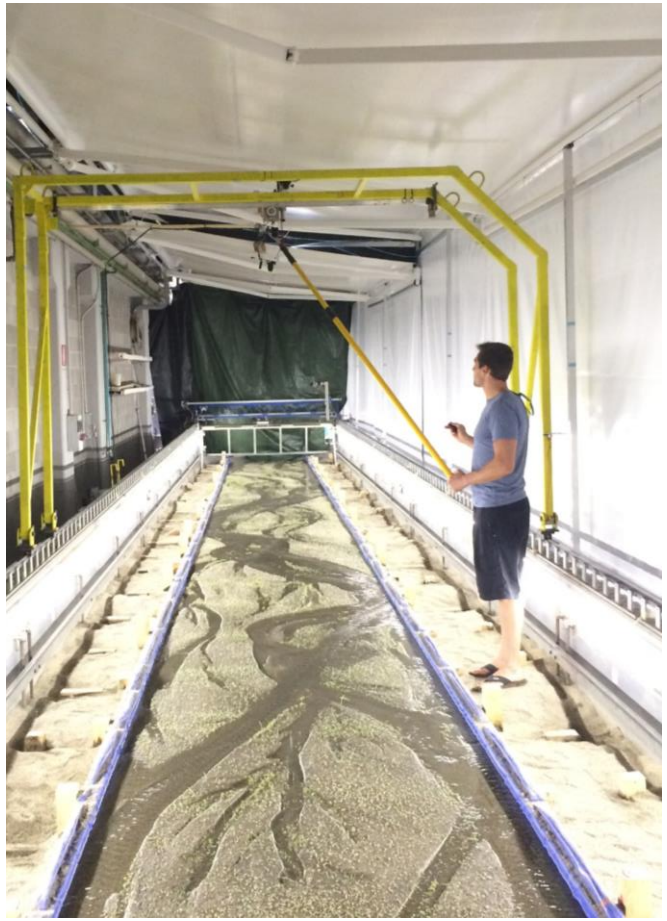
river science

CONTACT

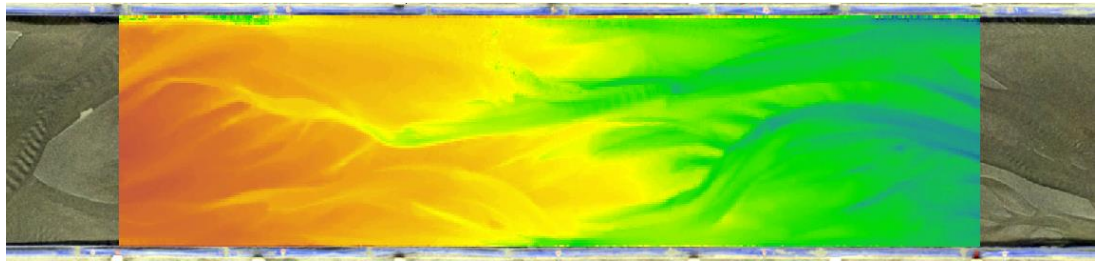
Luke Javernick

Luke@River.Science
719.428.9609

www.River.Science



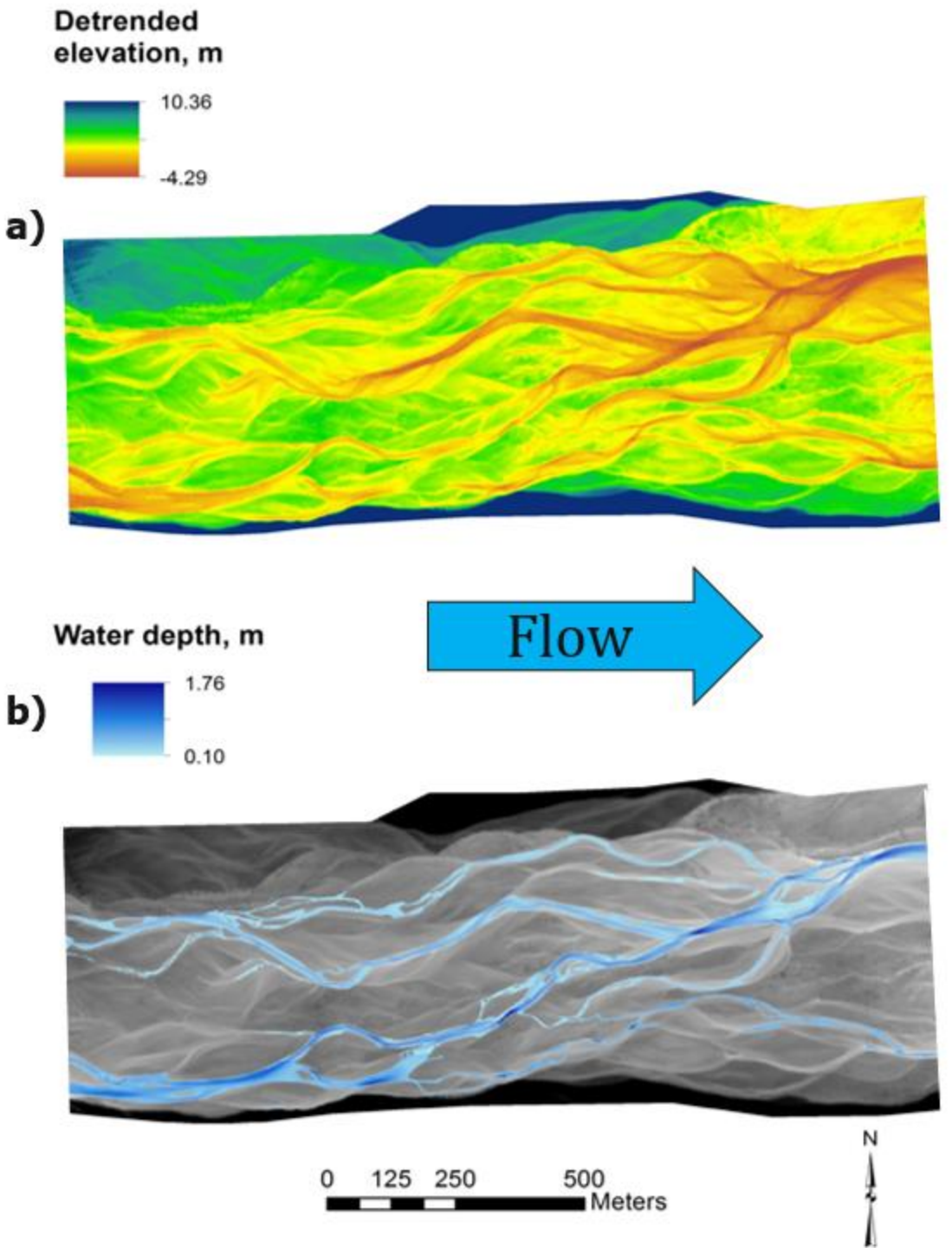
- Quantify vegetation and morphology changes
  - Produced DEMs: z errors 2 mm
  - Orthoimagery: 0.5 mm resolution
  - Photoscan following Javernick et al. (2014).



SfM: Why

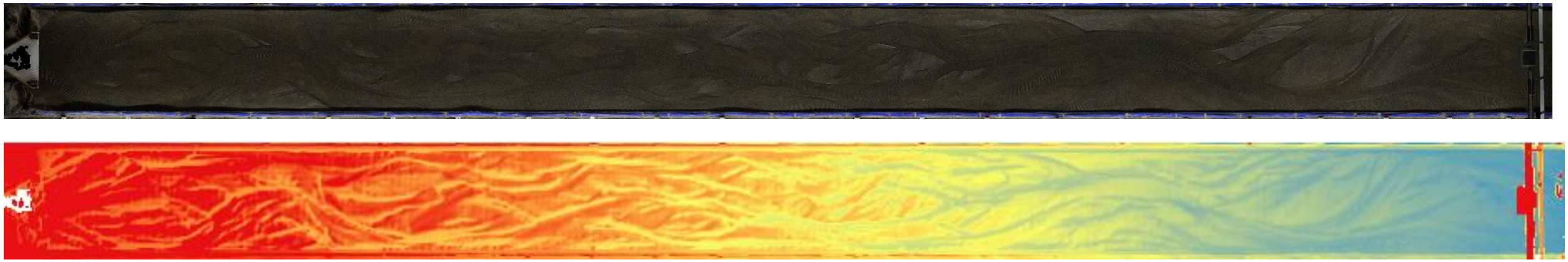
Field Example: Ahuriri

- 14 cm mean absolute error (bare ground)
- Faster and higher resolution than laser scanner
- Saved $14k over LiDAR, and subsequent surveys were cheaper.



SfM: Why

- Lab Example: Flume
  - 150 photographs
  - 12 minutes to capture
  - 3.5 m above the ground
  - Sub grain size resolution (< 1 mm)



SfM: Why

SfM: Why

- Field Example: Hydraulics Lab
  - 2.1 mm mean absolute erro
  - Faster and higher resolution
  - Simple to get data necessary
    - numerical models,
    - DoDs,
    - change detection

SfM: Best Practices

Camera settings

- Avoid compression images (like jpg)
- ISO should be set as low as possible to ensure clear images (don't wash out details with high light sensitivity).
- Aperture should be high enough to result in sufficient focal depth and to manipulate the optimal shutter speed.
- Shutter speed should not be slow enough to cause blur.

Lens

- 35 mm equivalent – you will have to calculate this for your camera.
- Fixed focal length is ideal. Otherwise, fix your adjustable focal length to be constant (near 35 mm equivalent).
- Keep it clean!
- Distortion. PhotoScan, the automatic distortion correction is more than adequate. If your accuracy is not what you expected, consider everything all the possible error sources listed above.
    - YOUR ACCURACY WILL NEVER BE BETTER THAN YOUR DATA.

Area

- Accuracy is only high in area bound by GCPs.