High Resolution Remote Sensing from a UAV for Quantifying Fluvial Topography

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1. Background & Context

The geomorphology of a river system is a key influencing factor on the physical habitat template[1]. It therefore also has a direct impact on the ecological quality of the fluvial environment. This work considers topography – a specific element of the fluvial geomorphology which can be defined as the size and shape of the channel bed (submerged) and the bank (emergent).

The quantification of variables such as fluvial topography is important for understanding and monitoring river habitat conditions and sustaining good river health.

Traditionally, fluvial topography is quantified using a series of cross sections where point measurements are taken at regular intervals across the channel. This typically involves the use of surveyor's levels & tachiometric staffs, mapping- or survey-grade GPS devices (Figure 1) or total station surveys. These approaches are time consuming, labour intensive and provide limited spatial coverage[2,3].

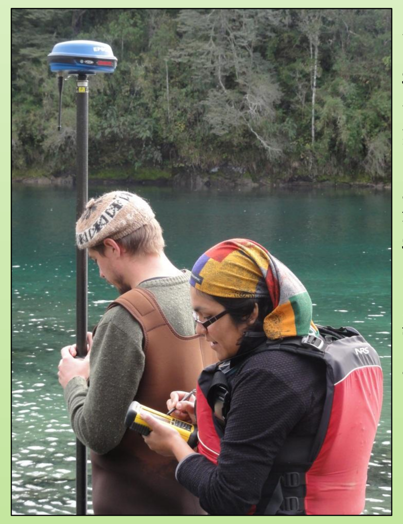

Figure 1. Surveying fluvial topography using a dGPS

2. Aims of this Research

Recent research has shown that the use of novel remote sensing approaches may provide an alternative to traditional methods of quantifying topography[4]. In particular, the use of cutting-edge unmanned aerial vehicles (UAVs) holds great potential for rapid, repeatable and inexpensive acquisition of accurate and very detailed aerial imagery[5,6,7].

The aim of this work is to assess the use of imagery collected using a UAV (Figure 2) for the generation of topographic datasets within fluvial environments. This forms part of a wider PhD study which is aiming to use high resolution remote sensing to assess other physical habitat parameters such as water depth, surface flow types, substrate and flow velocity.

Figure 2. The Draganflyer X6 – an unmanned aerial system

Research Questions

1) How accurately can we quantify topography using this approach?
2) Does the accuracy vary between dry and submerged areas, and why?
3) Do other factors affect the accuracy of the topographic data?
4) How does it compare to traditional and existing remote sensing approaches?

3. Site Location

One of the research sites used is a mesohabitat section of the San Pedro River, Chile (Figures 3 & 4). The size of this research site is roughly 200m by 40m.

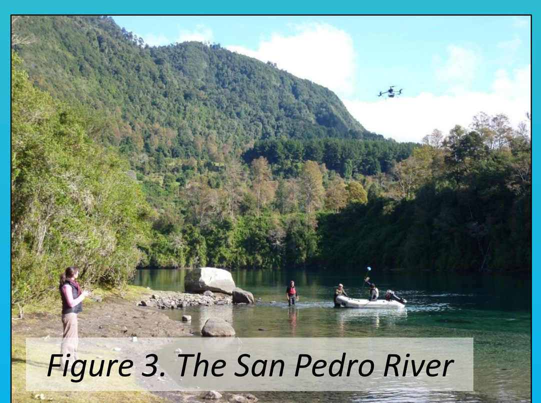

Figure 3. The San Pedro River

This site is the location of an on-going collaboration with the University of Concepcion concerned with characterising physical habitat conditions of native Chilean fish species, prior to hydropower dam construction.

Figure 4. Research site location

4. Data Collection

High resolution imagery was collected at the San Pedro River site in May 2012 using a consumer-grade 10.1 MP digital camera attached to a small, lightweight, rotary-winged UAV known as the Draganflyer X6 (Figure 2). Total flight time from 7 separate flights was c.45 minutes.

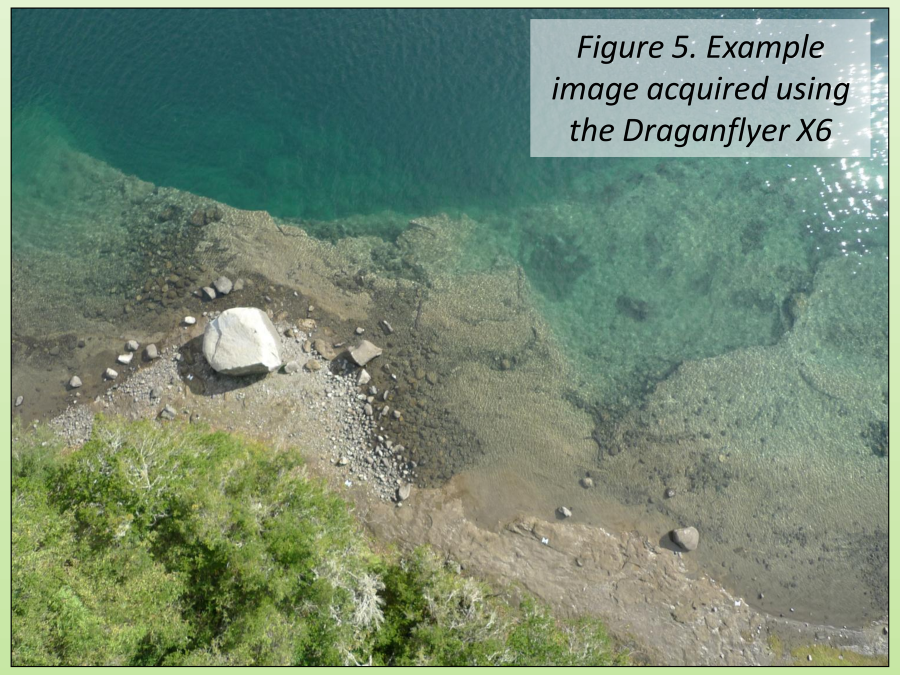

Figure 5. Example image acquired using the Draganflyer X6

The Draganflyer was flown c.25m above ground level to ensure collection of imagery at a consistently high resolution (<1cm). Camera calibration experiments had been carried out previously to establish the relationship between flying altitude, image resolution and image footprint size.

Images were collected with a high level of overlap (>80%) to allow subsequent image matching. Only vertical images free from blur and visible distortions were used for subsequent analysis (Figure 5).

A number of artificial ground control points (GCP) were made and distributed across the site prior to image acquisition (Figure 6). These were surveyed in using a Spectra Precision EPOCH 50 differential GPS (sub-cm accuracy) (dGPS), and used for subsequent geo-rectification of the imagery. The dGPS was also used to collect c.1700 elevation point values for the purpose of subsequent 'ground truthing'.

Figure 6. An artificial ground control point (GCP)

5. Image Processing

Images were mosaicked together using a 3D 'Structure from Motion' (SfM) software package called PhotoScan Pro (Agisoft LLP). This software works by matching points from multiple, overlapping images & estimating camera positions to reconstruct a 3D point cloud of the scene geometry[8]. When combined with the GCP positions, this process allows the creation of a high resolution orthophoto and a digital elevation model (DEM) of the research site (Figures 7 & 8).

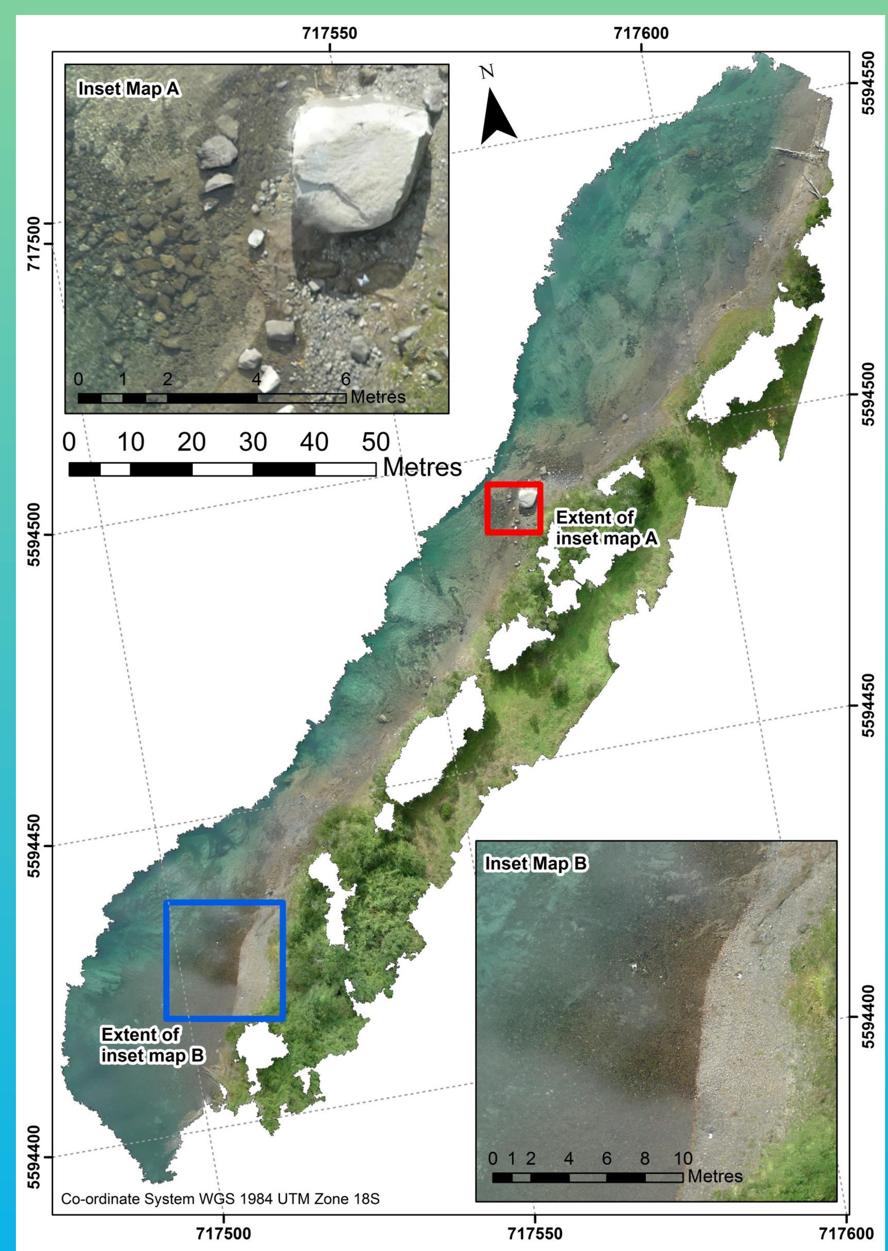

Figure 7. Orthophoto (spatial resolution of 0.7cm)

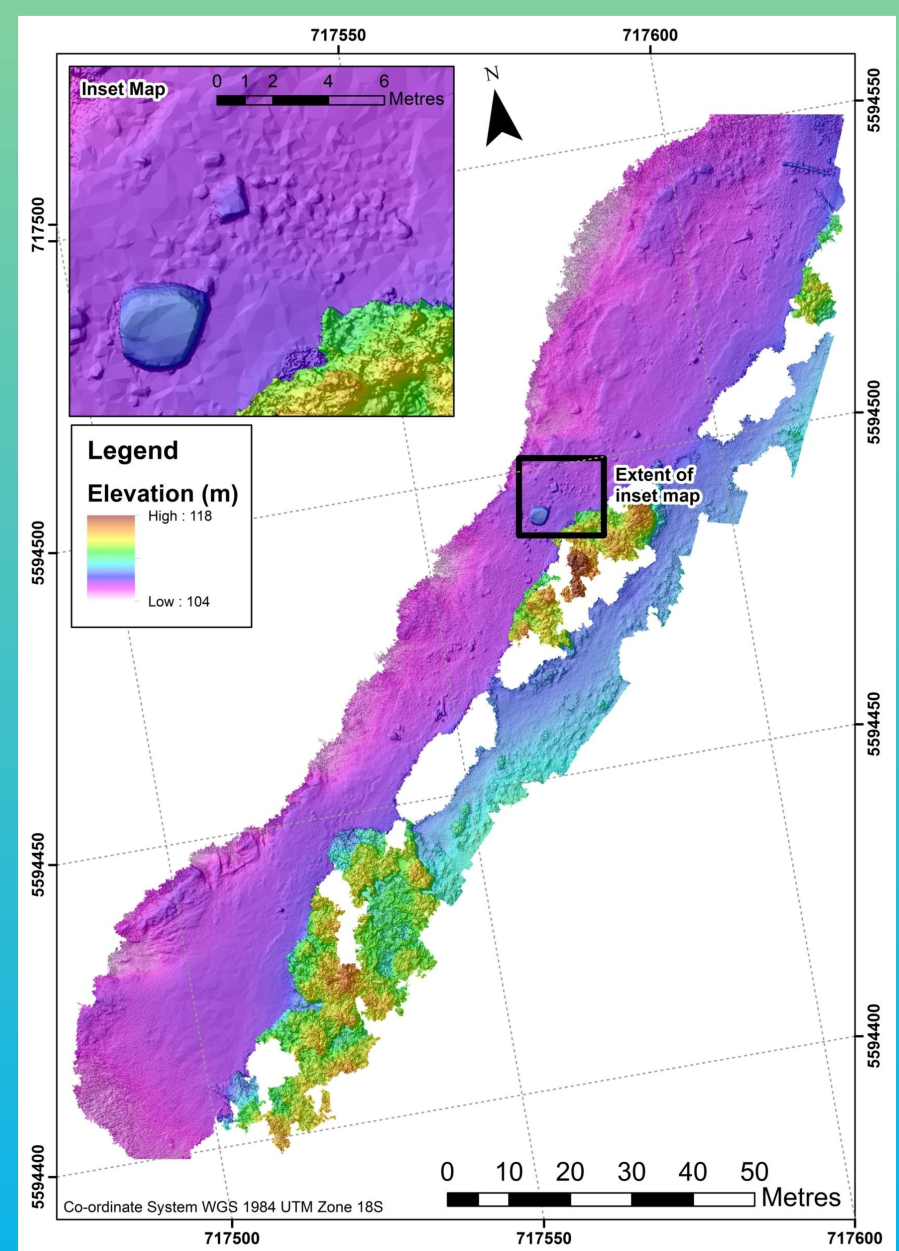

Figure 8. Digital Elevation Model (spatial resolution of 2cm)

6. Initial Analysis & Findings

Qualitative Analysis of the Orthophoto

- *Positives* – very high resolution allows easy identification of individual clasts as small as c.7cm, GCPs and submerged bedrock platform (Figure 9a).
- *Limitations* – some areas are adversely affected by surface rippling (Figure 9b), unwanted reflections and patches of visual distortion or holes in areas of trees and dense vegetation.

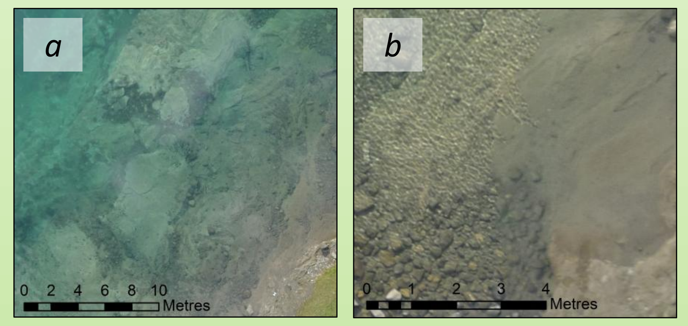

Figure 9. Close-ups for analysis of orthophoto quality

Quantitative Analysis of the DEM

- Analysis of the DEM is adversely affected by a systematic offset present in some of dGPS validation data of +5.93m.
- However, after removal of this systematic error the average error of the DEM is 3cm, and 66% of data sit within +/- 0.3m of the average error.
- The spatial distribution of error values is shown in Figure 10.

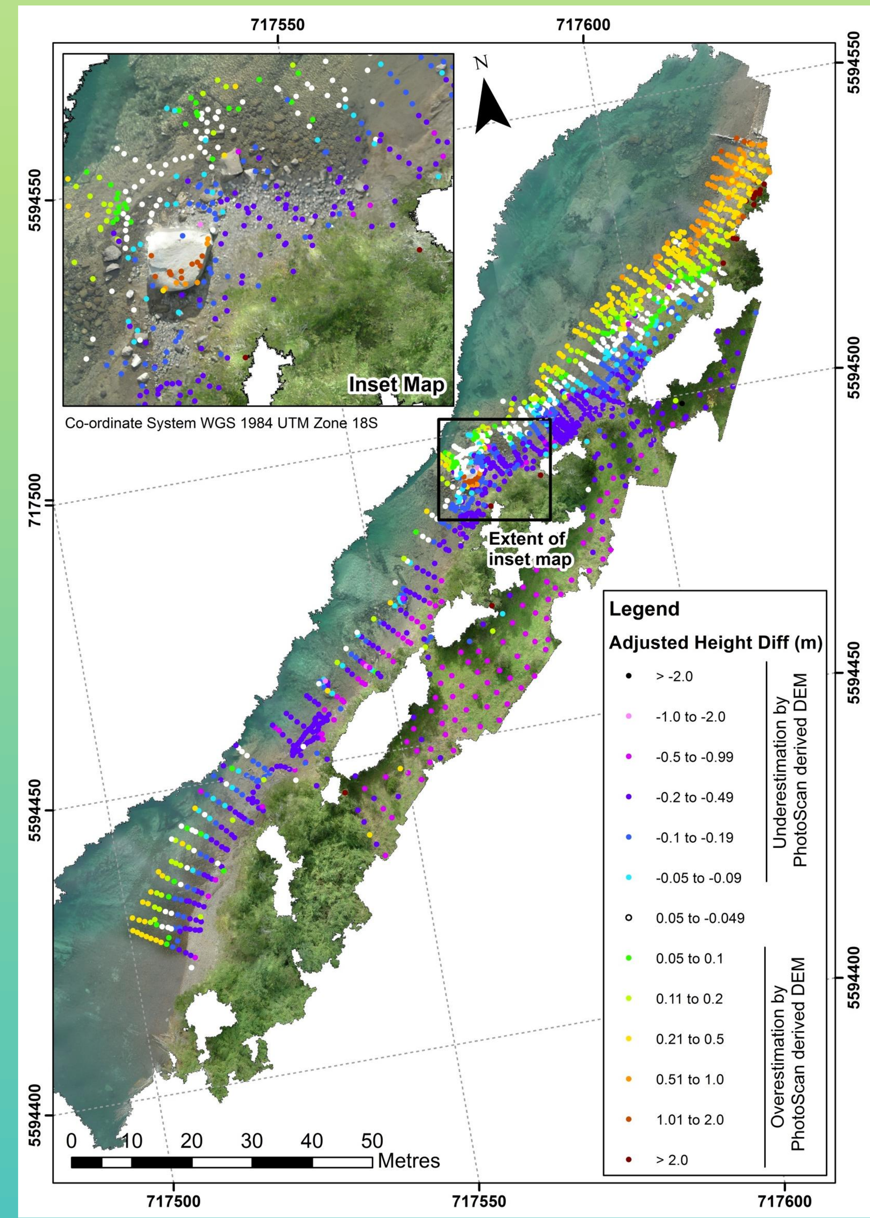

Figure 10. Spatial distribution of DEM error

DEM Accuracy by Land Cover Type (Fig.11)

- Overestimation of trees & dense vegetation large woody debris & boulders.
- Underestimation in areas of grass.
- No clear pattern in areas of exposed bank & submerged areas.
- On-going research is investigating the effects of light refraction in submerged areas.

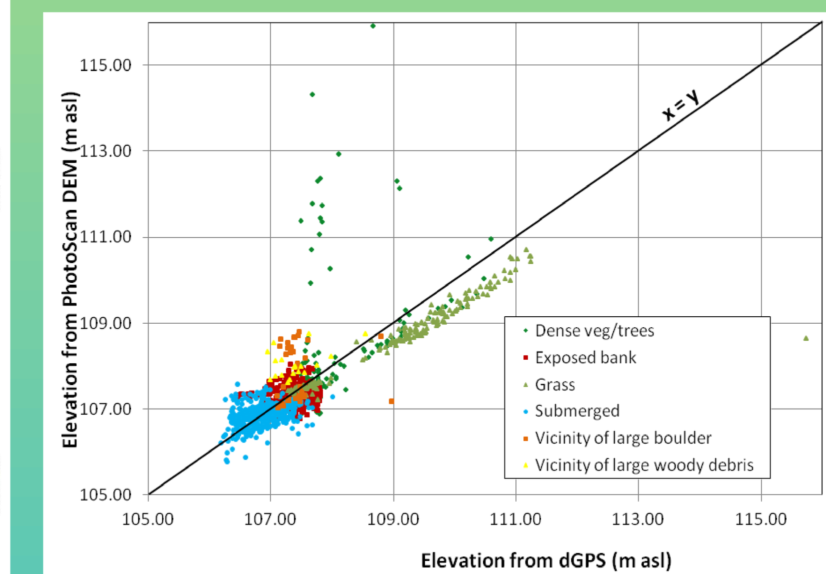

Figure 11. Differences between PhotoScan DEM & adjusted dGPS elevations values, by land cover type

7. Conclusions & Next Steps

Initial results indicate that the use of high resolution remote sensing from a UAV is a promising technique for quantifying the topography of fluvial environments at the mesohabitat scale. Key advantages include:

- ✓ High spatial resolution outputs (orthophoto & DEM);
- ✓ High average accuracy which is comparable to or better than that achieved using existing field-based & other remote sensing approaches (e.g. spectral-depth relationship method);
- ✓ Rapid, flexible, repeatable & relatively inexpensive.

Further research is required to explore the factors influencing DEM accuracy & the applicability of the approach to other river systems. Scheduled fieldwork in summer 2013 will also make a direct comparison of this technique with terrestrial laser scanning.

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