Full Paper

Vietz et al. 2021 Drones and Waterways

Assessing waterways from the sky: A new era in monitoring using drones

Vietz, G., Sutton, N., Houghton, J., Gower, T. and Lauchlan Arrowsmith, C.

Streamology Pty Ltd. Contact email: geoff@streamology.com.au

Key Points

- Drones are increasingly being used in waterway geomorphology, ecology and social monitoring
- Data focused projects can dramatically increase area, resolution and georeferencing of monitoring
- Linking drone-based data with hydrology dramatically increases flow operation guidance
- Despite dramatic advancements in drone technologies and analysis we are still required in the field

Abstract

Monitoring of waterway ecology, geomorphology and values have for a long time involved arduous days in the field with lots of time on hands and knees. Field methods have also been limited in recognising patterns or explicitly linking to drivers of change such as flow. The use of Unmanned Aerial Vehicles (UAVs) or 'drones' has dramatically increased opportunities and our understanding. We have been developing drone waterway monitoring methods and analyses over the last three years that go well-beyond simple imagery, and are now being applied to understand the links between flow, riverbank geomorphology, vegetation and cultural values. We present examples from the Murray Darling Basin including the River Murray, the Goulburn River (Victoria) and the Edward-Wakool (NSW). Findings include: an ability to dramatically increase the area of interest and georeferencing leading to greater recognition of patterns; higher resolution data leading to process-based understandings; direct linkages to hydraulic and hydrologic models to explicitly identify the role of flow; and perspectives that enable waterway values to be better characterised and stories to be told. Drone monitoring is considerably advancing our ability to identify the interactions between flow management and modify operations accordingly, whilst also enhancing engagement opportunities with stakeholders and the community. The sky is the limit!

Keywords

Monitoring, drone, geomorphology, riparian vegetation, river operations

Introduction

The key question discussed in this paper is: *how can we use drones to better effect in waterway monitoring and management?*. There are four key challenges we have as waterway managers, or for those who monitor waterways:

1) Waterways are not the most accessible workplace. Yet, as ecologists, geomorphologists and waterway managers we are often required to collect data, or assess condition, by getting to the 'coalface', or river, or water line, or patch of vegetation. This is often extremely difficult due to the terrain and can pose safety risks, or will often impose limitations on the length or area surveyed or assessed, or the detail provided by the assessment. Add to this limited timeframes within which work can be achieved due the requirement for appropriate water levels.

2) Data is increasingly being recognized as the centrepiece of robust and rigorous findings. Whilst observation and subjective assessment still play a role, there is an increasing need to objectively quantify 'something' measured. There is also an increasing desire to capture data for larger areas, avoiding the bias provided by a small area or site. At the same time there is also interest in higher resolution information so that greater detection, or earlier detection, can be made.

3) Locating and re-locating changes to rivers increasingly requires spatial referencing. Such as how much a riverbank has receded, or where vegetation has moved to. Particularly when repeat measurements that need to be 'tied' together.

4) Linking it all together. There is an increasing understanding of the complexity of natural systems such as waterways, as well as recognition of interactions. To better understand waterways now requires understanding these interactions, such as between hydrology and geomorphology e.g how riverbank erosion links to flow characteristics of operations, or ecology e.g. how vegetation patterns link to inundation characteristics (Figure 1). We recognize within this point, the importance of geomorphologists gaining field knowledge, observations, and the important role in interpreting data.

Figure 1. Bank erosion and loss of vegetation are related to flow operations, and verifying this relationship requires spatially explicit methods.

Can these challenges in waterway management be addressed with drones?

Drones are now more than a mere toy. The use of drones, or Unmanned Aerial Vehicles (UAVs), worldwide for almost anything, and everything, has increased dramatically, with scientific interest demonstrated by the international journal 'Drones' (Publisher MDPI). Yet, the majority of uses for drones in waterway management is pretty pictures (with 'drones for data' being the exception). Of course aerial imagery is a fantastic, and repeatable, resource with valuable applications. There are reports that UAV technology is '*essential for unbiased assessment of our waterways*' (Green et al. 2021). With rapidly increasing technology can drones really increase the efficiency and effectiveness of waterway monitoring and management?

We know flow causes change in riverbank morphology, geomorphic processes, and vegetation zonation and condition (Vietz et al. 2017). Riverbank condition can be directly correlated to flow. Under hydrologic changes such as our changing climate, or flow operations, there will be a direct geomorphic or vegetative response. Explicitly linking these changes to flow operations, or natural or environmental flows, will improve our ability to manage these systems.

With a basis in international research, Streamology has been developing a new drone-based riverbank morphology and vegetation condition surveying method over the last three years, Figure 1. Using drones has challenged the team to push their limits across various aspects including; close proximity flying (accepting the occasional submersion!), increased spatial referencing and accuracy (beyond what can be observed) and computational analyses (requiring of computational power). The challenge has been worth it, as using drones can provide far superior insights compared with previous monitoring methods. These findings are supported by studies that find UAV-based riverbank surveys are more accurate than those with traditional surveys, and even when compared to terrestrial laser scanning approaches (Benjamin et al. 2020). The challenge is still whether we can deal with the sheer volume of data obtained from these approaches.

Figure 2. A pilot's view of undertaking geomorphology using drones (Goulburn River, Victoria). Photo (and pilot): Neil Sutton

Geomorphology from the sky

Streamology staff have been undertaking physical habitat monitoring, including hydraulic habitat (hydraulic modelling) and bank condition monitoring for more than 10 years. At that stage the most advanced method for measuring erosion and deposition was through the use of erosion pins. Needless to say, the erosion pin method limits our understanding, and it is spatially discrete (only single points in space), limited to good access, prone to loss, impactful on result, and extremely arduous. In particular, erosion pins provide little understanding of erosion patterns and hence process is difficult to determine.

Whilst drone technology and processing is ever-advancing the currently used main method incorporates photogrammetry. This can be explained as being similar to walking around a chair and blinking 50 times to develop, in your brain, a 3D image of the chair. This method has been around for some time (Snavely et al., 2006), but it is the recent improvements in accuracy, and methods required to capture and spatially map functional plant groups, or erosional and depositional features, that has allowed the latest possibilities.

To understand riverbank morphology, and demonstrate processes, changes are assessed as erosion and deposition to understand the pattern and volume of change (James, 2017). To do this, two Digital Elevation Models (DEMs) of the same riverbank, before and after a flow event (or series of events), are compared to create a DEM of Difference (DEMOD). This process results in a visualisation that highlights areas and depths of deposition and erosion across a riverbank (Figure 3).

The benefit of drones for geomorphic monitoring is that they enable explicit geo-referencing, something that was not previously possible. Using satellite and ground control points, drones enable repeat before and after monitoring (Sutton et al., 2020a). This allows direct comparisons to be made over time – changes that can be attributed to flow conditions (Figure 4). How erosion corresponds with the flow regime can be linked through the hydraulic models tied to the same spatial datum.

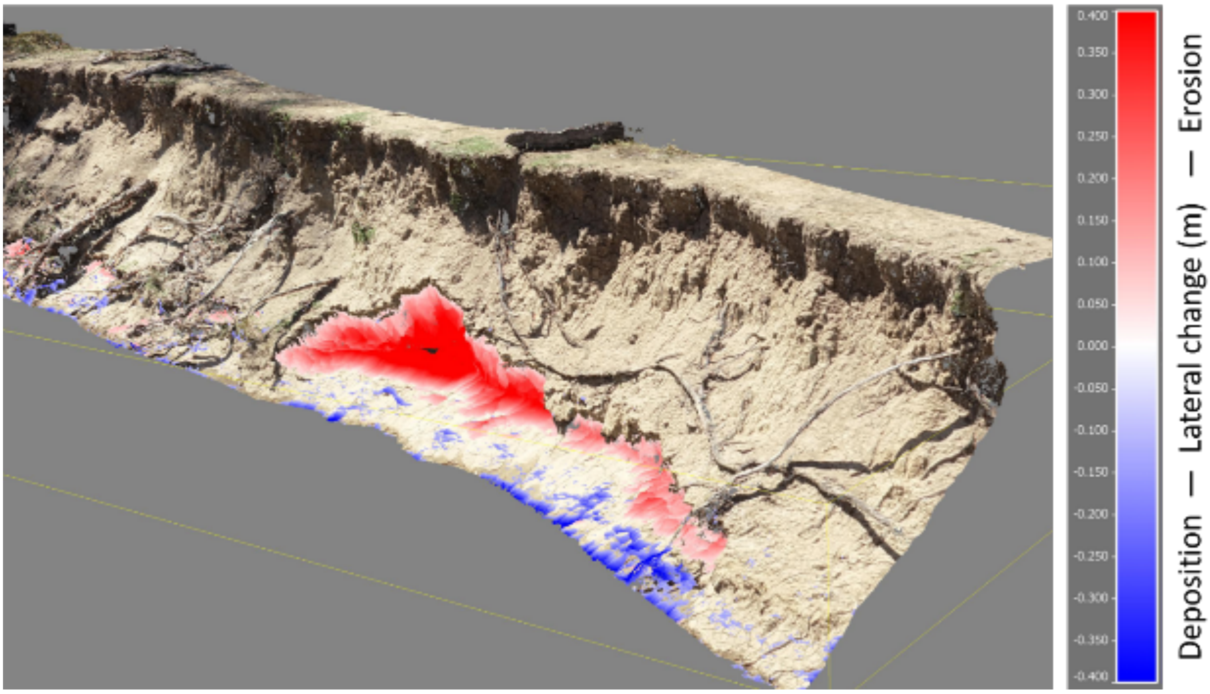

Figure 3. What erosion looks like in a Digital Elevation Model of Difference. Comparison of two periods in time highlight erosion (red, up to 0.4 metres) and deposition (blue). The picture is a combination of x,y,z data points, with a colour pixel associated, so that an 'image' is recreated from data. Edward Wakool River, NSW.

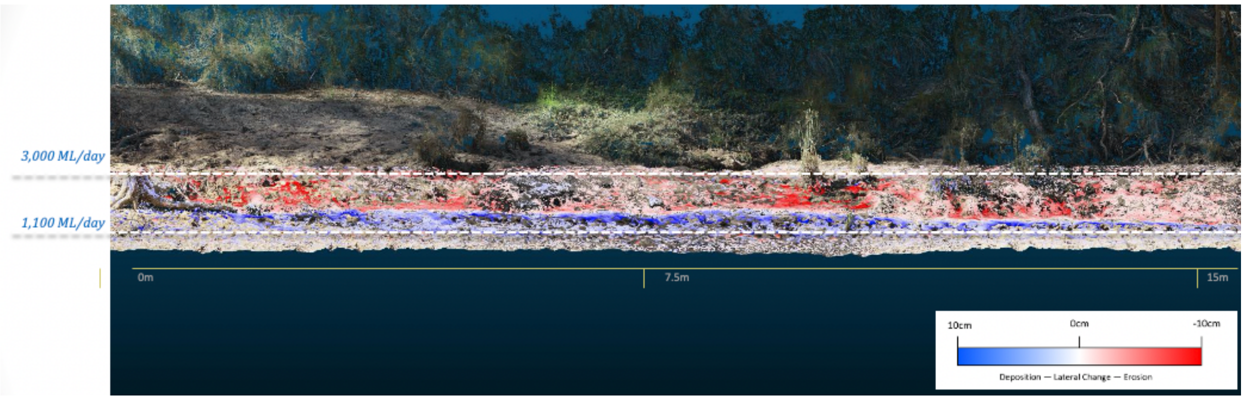

Figure 4. Erosion (red) and deposition (blue) indicating geomorphic processes relative to baseflows (1,100 ML/d) and upper levels of regulated flow transfers (3,000 ML/d). Goulburn River, Victoria.

The findings from this work then enable understanding of patterns and linkages. For example, it has been found within both the Edward/Kolety River and the Goulburn River, that periods of prolonged summer irrigation flows prior to an environmental flow can prepare a riverbank for mass failure (slumping) erosional events (Sutton et al., 2020a; 2020b; Vietz et al., 2021). This sequence of flow events creates a 'notch' (or water mark) during the prolonged irrigation period, saturating and reducing the stability of the upper bank during the rise and fall of the subsequent large environmental flow event (Figure 5). These findings are guiding waterway managers on how to effectively deliver large volumes of water whilst minimising damage to the waterway and the ecological values it supports.

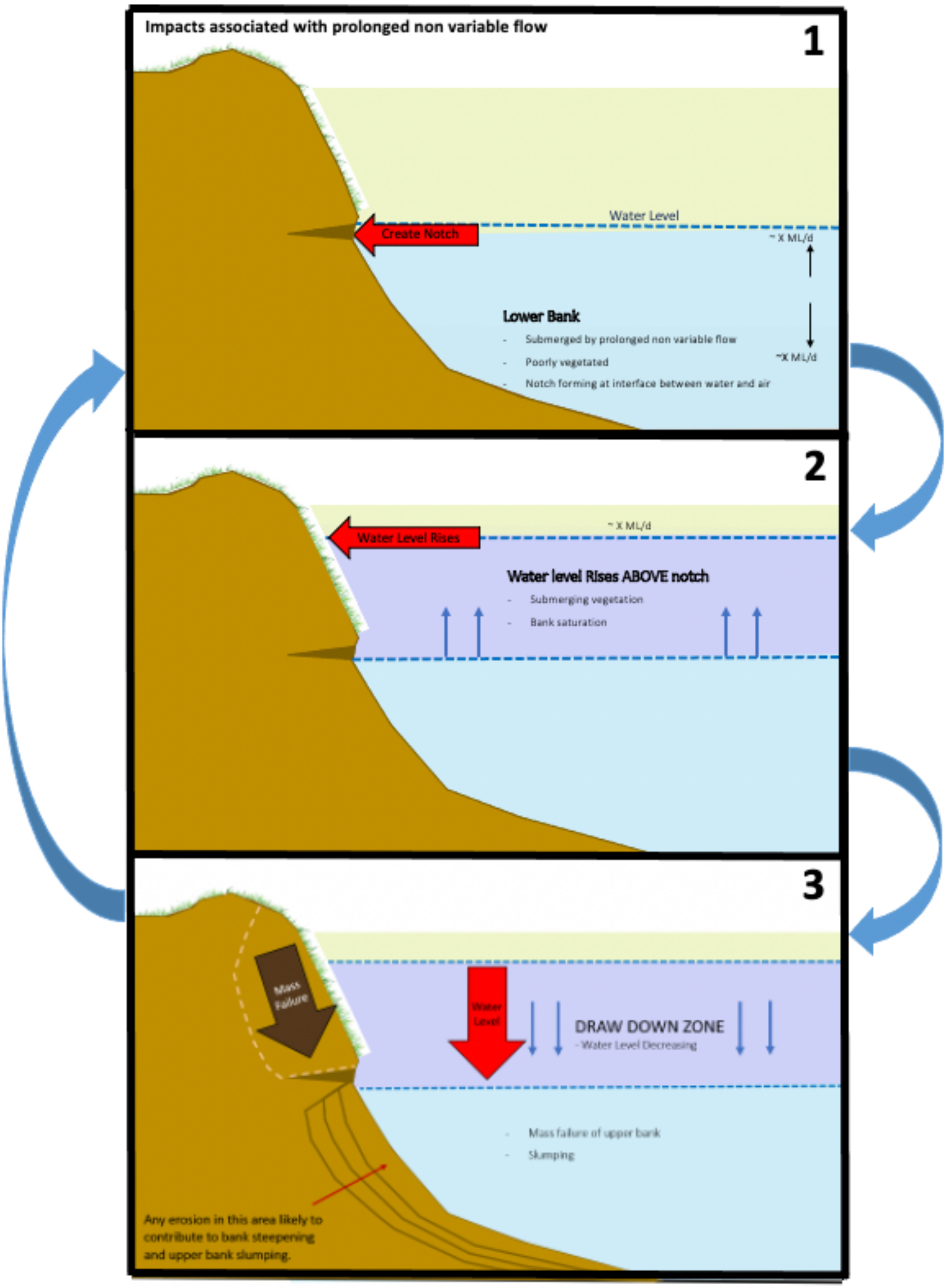

Figure 5. The conceptual three stage erosion process for erosion in regulated rivers, demonstrated using drone monitoring.

Vegetation with a birds eye view

Vegetation is monitored with drones in two ways: 1) using either cover changes from measurements within DEMODs, or 2) 2D vegetation map comparisons (Sutton et al., 2020a). The former draws upon 'data' of vegetation location, height and colour and the latter uses hundreds of drone images taken from a birds-eye-view to create a 2D map. Two vegetation maps of a site (surveyed before and after a flow event) are then compared and spatial extents of change calculated in response to a particular flow event (Figure 6). The use of multi-spectral is a third option for vegetation comparison, with details beyond the scope of this paper.

When considering the interactions between bank sediment change, and vegetation cover and density, results have supported the general consensus that increased vegetation cover leads to improved bank stability and resilience, and in turn that increased bank stability and resilience leads to increased vegetation cover (Vietz et al., 2021). Prior to the development of the drone method, collecting evidence to support the relationship between these processes was challenging due to the spatial limitations of transect (linear) derived vegetation monitoring.

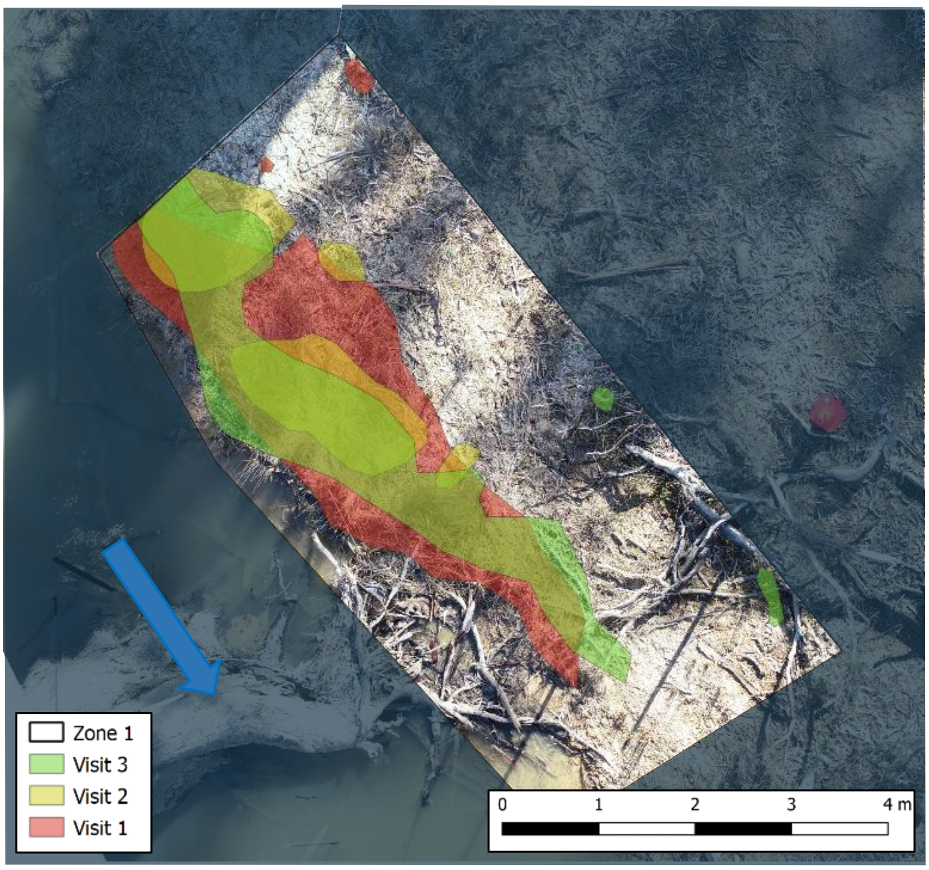

Figure 6. Drone derived vegetation change map highlighting vegetation cover captured during 3 replicate drone surveys on Colligen Creek. Significant spatial changes in vegetation cover were linked to variations in inundation periods linked directly to flow events.

Other options for drones in waterway management

The opportunities for the use of drone data also include:

- Assessing fire and flood impacts, including sub-catchment scale changes in slope and gully topography resulting from sediment movement. These datasets, and the resulting images, also provide valuable community engagement tools. Recent assessments on Nariel Creek, Victoria, provide a demonstration of this work (Rutherfurd et al. 2020).
- Social and cultural values, including the effects of flow regulation relative to the location of indigenous sites of significance. Recent assessments provide a demonstration of this work but cannot be described at this stage. The spatially explicit nature of the data must also consider the sensitivity of locating sacred sites.
- Biota monitoring, including an assessment protocol for monitoring platypus, developed in conjunction with the Australian Platypus Conservancy (see Gower et al. 2021 in this proceedings). This method,

trialled on the Goulburn River in Victoria, draws upon the limited air supply by platypus, and the need to surface over a short time period. The opportunity to cover large areas, improve the binary approaches to presence/absence, and reduce the otherwise arduous nature of platypus monitoring approaches. The method requires further testing with respect to periods of movement and coordination with movement and at this stage is more amenable to larger rivers.

Limitations

- The method of photogrammetry doesn't see through water, as with standard LiDAR. This limits opportunities during higher flow periods.
- Photogrammetry doesn't see through vegetation as well as LiDAR. So whilst it is often vegetation we are monitoring, the absence of vegetation can actually relate to more accurate topographic data. It is important to then avoid bias in monitoring toward clearer areas of waterways, and requires high confidence flying beneath tree canopies.
- Vegetation condition is difficult to assess using drones due to shading and contrast. In particular riverbank vegetation can look dead when it is merely 'mud draped'. Seasonal changes in certain vegetation types such as colour and size can make cover changes across the year difficult to provide robust insights on.

The importance of fieldwork interpretation and verification of drone derived data

Drone monitoring and surveys will never negate the need, or reduce the value, of observations made in the field. There is an immediate need to go to the field to collect drone data, and the value of this is important when the operator is involved in interpretation. There is also a need to verify data that is collected in the field, including post-analysis of data, as supported by Fryirs et al. (2021). Most importantly, observations in the field take into consideration a range of considerations not possible in automated data collection. For the bank condition described in this paper many of the conceptual models and intrepretations are based on prior field-based inspections (Vietz et al., 2017, Vietz et al., 2016). As highlighted by Fryirs et al. (2021), human skills at reading and interpreting the landscape are still fundamental to the process.

Conclusions

Irrevocable changes to riverbanks (deep incision, bank steepening or channel widening), or changes to riparian vegetation such as through prolonged inundation or velocity patterns can significantly alter ecosystem function. Demonstrating a response and explicit link to the impacts of flow, allows us to understand impacts and modify management, to achieve the best outcomes for healthy rivers. Furthermore, linking social and cultural values, or presence and activity of biota, to flow conditions will also improve our understanding of how our management drives changes, and how we reduce impacts.

Drones in waterway management provide: an opportunity to increase safety and accessibility in waterway monitoring; they dramatically increase the area of interest and georeferencing opportunities leading to greater recognition of patterns; they provide higher resolution data leading to process-based understandings; they enable direct linkages to waterway change drivers such as through hydraulics and hydrology, and; they provide perspectives that enable waterway values to be better characterised and stories to be told (including through pretty aerial pictures). Drone monitoring is considerably advancing our ability to identify the interactions between flow management and modify operations accordingly, whilst also enhancing engagement opportunities with stakeholders and the community.

Of course, despite the potential opportunity to send a drone to the field without leaving your office carpark, there will always be the need for field inspection by trained and experienced observers. Some of the best ideas for the protection and improvement of waterways still occur in the field.

Acknowledgments

We would like to thank funding agents including the Commonwealth Environmental Water Office (contact: Kerry Webber), Goulburn Broken Catchment Management Authority (Daniel Lovell), Victorian Environmental Water Holder (Rebecca Curran), Melbourne University (Angus Webb) and Charles Sturt University (Robyn Watts). We thank Kirsty Fryirs for valuable comments that improved this paper.

References

Benjamin U. Meinen & Derek T. Robinson (2020) Streambank topography: an accuracy assessment of UAV-based and traditional 3D reconstructions, International Journal of Remote Sensing, 41:1, 1-18

Fryirs, K., Wheaton, J., Bizzi, S., Williams, R., and Brierley, G., 2021. Do we still need a human? Geomorphic analysis and interpretation of river systems in an age of emerging technology and big data. Proceedings of the 10th Australian Stream Management Conference 2020, Kingscliff, NSW.

Gower, T., Vietz, G., Lauchlan Arrowsmith, C., 2021. A new approach to measuring waterway physical habitat for biota. Proceedings of the 10th Australian Stream Management Conference 2020, Kingscliff, NSW.

Green, D., Gregory, B., Karachok, A., 2021. Unmanned aerial remote sensing : UAS for environmental applications. Boca Raton : CRC Press, 2021.

James, M. (2017). Precision maps and 3-D uncertainty-based topographic change detection with structure-from-motion photogrammetry.

Rutherfurd, I., Gower, T., Vietz, G., Arrowsmith, C.,2020. Geomorphological assessment of the Nariel and Corryong creeks in the Upper Murray. Report by Streamology for the North East Catchment Management Authority, 2020.

Snavely, N., Seitz, S., & Szeliski, R. (2006). Photo tourism: exploring photo collections in 3D. ACM Transactions on Graphics (TOG), 25(3), 835–846. http://dl.acm.org/citation.cfm?id=1141964

Sutton, N., Houghton, J., Vietz, G., Jones, C., Mole, B., Morris, K., and Gower, T. (2020a). Influence of Intervalley Transfers (IVT) on the Riverbanks and Bank Vegetation of the Goulburn and Campaspe Rivers. Report by Streamology and Arthur Rylah Institute for the Department of Environment, Land, Water and Planning. June, 2020.

Sutton, N., Houghton, J., Vietz, G., Jones, C., Mole, B., Morris, K., and Gower, T. (2020b). Monitoring, evaluation and research assessment of geomorphic and vegetation change on the Edward (Kolety) and Wakool Rivers in response to environmental flows. Report by Streamology and Arthur Rylah Institute to Charles Sturt University. August, 2020.

Vietz, G., Casanelia, S., Earl, G., Conlan, I., Johnson, C., 2016, Knowing then doing, or is it doing then knowing? Environmental flows and bank condition monitoring in the Goulburn River, Australia. Paper 26972, In: Proceedings of the 11th International Symposium on Ecohydraulics, Conference, 7-12 February 2016, Melbourne, Australia, The University of Melbourne.

Vietz, G. J., Lintern, A., Webb, J. A., Straccione, D., 2017, River bank erosion and the influence of environmental flow management, Journal of Environmental Management, doi: 10.1007/s00267-017-0857-9.

Vietz, G., Sutton, N., Gower, T., and Houghton, J. (2021). Monitoring, evaluation and research assessment of geomorphic and vegetation change on the Goulburn and Campaspe Rivers in response to environmental flows. Report by Streamology Pty Ltd to the University of Melbourne. July 2021.