NSW Beach Photogrammetry: A New Online Database and Toolbox

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Abstract
The NSW government has acquired extensive aerial imagery of the coastline. Using stereo-photogrammetric techniques, around 10,000 survey transects have been extracted to-date along NSW's 990 km sandy beach coastline, dating back to the 1930s at some locations. Recent advances in survey technology, such as airborne LiDAR, UAV surveys and ground laser surveys are reducing the cost and the difficulties of obtaining large-scale beach surveys. As these technologies evolve, surveys are becoming more frequent, highlighting the need to move to a structured, accessible database.

Along the NSW coast, the photogrammetry profiles provide the raw data from which long-term trends of beach change can be assessed. However, this data has only been available when individually requested from Office of Environment and Heritage (OEH). To make this data more accessible and to promote its wider use, the statewide dataset of beach profiles is available via the new '*NSW Beach Profile Database'* online interface and toolbox. This online database incorporates a user-friendly interface to access profile data as well as a range of visualisation and analysis tools. These include the visualisation of changes in beach cross-sections and some commonly used coastal analysis tools, such as timeseries analysis of the cross-shore location at any beach elevation contour and sand volume changes at any profile along the NSW coastline. It is anticipated that bringing this information into a user-friendly, internet-based format will better facilitate easy access and analysis of beach trends that can inform coastal management and planning decision-making along the NSW coastline. This paper provides examples of data visualisation and analysis tools that are available, along with an overview of the underlying data structure of the new beach profile survey database.

Keywords: photogrammetry, beach survey, profile analysis.

1. Introduction

Photogrammetry is the process through which georeferenced images can be used to extract survey data and three-dimensional surfaces from photographs, traditionally taken from an aeroplane. Two or more images are processed through a stereo-plotter to extract the data.

The NSW Government has extensive aerial records of the state's beaches, dating as far back as the 1930s. By using stereo-photogrammetric techniques, these photographs have been processed into profiles along the NSW coast. At each beach, data has been extracted at representative transects along the beach, typically at a spacing of 20 – 200 m, with transect location kept constant across survey dates (an example is shown in Figure 1). Cross-shore point density of the processed profiles varies, but is typically in the order of 10 – 20 points per profile. Historic survey frequency ranges between 1 to 20 years at most beaches.

Technology is evolving and large scale surveys of beaches are becoming more accessible and frequent. The use of airborne LiDAR (Light Detection And Ranging), ground laser surveys and advanced photogrammetric techniques employed by drone users have rapidly increased the size and frequency of aerial surveys. As such, the amount of data held in the beach profile records in NSW has grown substantially.

With such a large dataset, the information has become increasing valuable to assess the natural variability and long term trends of beach change. To increase the accessibility of this data, an online database and toolbox has been developed that is open for public use. The database and

Figure 1: Example transect locations at Freshwater Beach

corresponding online interface is called the '*NSW Beach Profile Database'*, and will be available at www.nswbpd.wrl.unsw.edu.au.

2. History

In the 1970s, several large storms impacted the NSW coast, causing significant coastal erosion. The erosion damaged and threatened infrastructure at many beaches across the state, particularly in the Sydney region. The effect of the storms highlighted the vulnerability of coastal communities in NSW to coastal erosion and long term coastal change. In response, the Public Works Department (PWD) began to fund periodic, large scale aerial photography of the NSW coast for photogrammetric analysis.

In addition to the photography commissioned in the 1970s, historical aerial images were also analysed, often dating back to during the Second World War and at some locations a decade earlier. While it is well understood that all beaches are dynamic environments that are constantly varying, the intention of this program was to provide long term, good quality and frequently sampled survey data to assess how variable each beach is. As technology has developed, particularly during the last decade, the photogrammetry has been supplemented and replaced by modern aerial survey techniques, including LiDAR and drone surveying.

3. Survey Accuracy

The accuracy of photogrammetry is dependent on many factors, including the height at which the image was taken, distortions for physical features of the land (including the curvature of the earth and relief displacement), and distortions from the camera. While all modern cameras used for photogrammetry are calibrated to allow such corrections, no such calibrations were performed for camera distortions prior to 1960 [5]. Pre-1960's surveys are therefore less accurate. A number of studies have compared GPS ground control to the photogrammetry survey data at numerous specific sites in NSW (e.g., [4]&[5]). Table 1 summarises the accuracy of the aerial photo surveys.

Recently, there have been significant developments in survey techniques, including ground laser surveys, aerial LiDAR and drone surveys. Some post 2010 data provided in the NSW Beach Profile Database may be derived from these modern survey techniques. Table 2 tabulates the approximate vertical accuracy that can be expected from these techniques. The horizontal accuracy of drone and LiDAR surveys is related to the survey methodology (including flight altitude and the use of ground control points) however is generally of a similar order to the vertical accuracy.

Table 1: Accuracy of Photogrammetry (source: [3])

Year	Vertical Accuracy (m)	Horizontal Accuracy (m)
Pre-1960	±0.7	±1
Post-1960	±0.2	±0.5

Table 2: Accuracy of Modern Survey Techniques for Beach Applications

Technique	Vertical Accuracy (m)
Ground Survey	± 0.05
LiDAR [8]	± 0.15
Drone [9]	±0.07 (where no vegetation is present)

4. The Online Database

The NSW photogrammetry data has traditionally been stored in text files that are held by the Office of Environment and Heritage (OEH). To implement the new online *NSW Beach Profile Database* these files have been processed into a MySQL database, using custom written python codes. The processing procedure included automated searches for files in the correct format, as well as visual inspections of data and manual adjustment of files as required. As this dataset spans such a long period of time, the profiles had originally been extracted into three different coordinate systems, including the Australian Map Grid (AGD66 AMG), Integrated Survey Grid (AGD66 ISG) and the Map Grid of Australia (GDA94 MGA). While data is entered to the database in its original coordinate system, a custom python code was written to convert all the coordinates into GDA94 MGA. This is the current accepted projected coordinate system used across Australia, and brings all the data into a single system for ease of use.

This enables the data to be easily queried, accessed efficiently through online platforms, and is sufficiently flexible to cope with the anticipated continuing increase in future survey density and frequency.

To facilitate public access and the implementation of a range of new visualisation and profile analysis tools, the MySQL database has been coupled with a Django [2] web framework. Django is a python-based [7] platform that provides a powerful web application builder, particularly used for database-driven websites. Python, as a scientific programming language, is well suited to dealing with large datasets and performing large scale analyses, such as those used in the online toolbox. Finally, the website is served via an Apache HTTP [1] web server. Apache is currently the most commonly used, open source web server application worldwide.

5. Capabilities and Uses

The *NSW Beach Profile Database* includes survey information from more than 10,000 cross-shore profiles, at hundreds of different beaches along the NSW coast. By presenting the information in an online interface, users are able to access the data collected over the last 85 years, as well as perform several common coastal engineering calculations and analyses.

At each location, shore normal survey profiles are distributed along the beach at typical spacing of 20 m – 100 m alongshore. Each profile location is viewable via a Google Maps display that is integrated within the *NSW Beach Profile Database*. The user selects one or more of the profiles to view the data and use the online coastal toolboxes. The toolbox capabilities are discussed in the following section and include:

- Visualisation of profile data;
- Cross-shore movement of a selected contour;
- Sand volume change; and
- Data and shapefile downloads.

The portal draws graphs, which can be exported as images. Alternatively, all data is available for download as a CSV.

5.1.1 Raw Profile Data

The visualisation of the raw profile data simply provides a plot of the chainage and elevation of the profile at each available survey date (for example, Figure 2). Data can be downloaded and is supplemented by positional data (provided in GDA94/MGA Zone 55/56/57 as appropriate). Shapefiles of the profile locations can also be downloaded.

5.1.2 Cross-shore Movement of Selected Contour

The contour timeseries provides an analysis of the location of the chainage to a chosen elevation contour on a profile (default 2 m AHD contour, but this can be changed.) Higher elevations can be used to examine changes in dune or escarpment locations. This will give a better indication of long-term accretion/recession trends on the beach [9]. The result is a timeseries plot that shows the chainage of the contour, and the year of the survey.

This tool utilises linear interpolation between survey points to return the most seaward location of the chosen elevation. However, it will not perform any extrapolation. This means that if an elevation below the minimum height of the survey is selected, no value is returned. Typically, the data will extend down to 0 - 1 m AHD.

5.1.3 Sand Volume Change

The volume timeseries calculates and displays the volume of sand above a chosen elevation, seaward of a chosen baseline. This tool requires five parameters that can be adjusted by the user, including the landward limit of the analysis and the reference elevation above which volume is calculated. Other options, including the extrapolated beach profile, are provided for advanced users.

In this volume tool, the measured profile is extrapolated to the chosen elevation if required. By default, it will be at the same gradient as the most

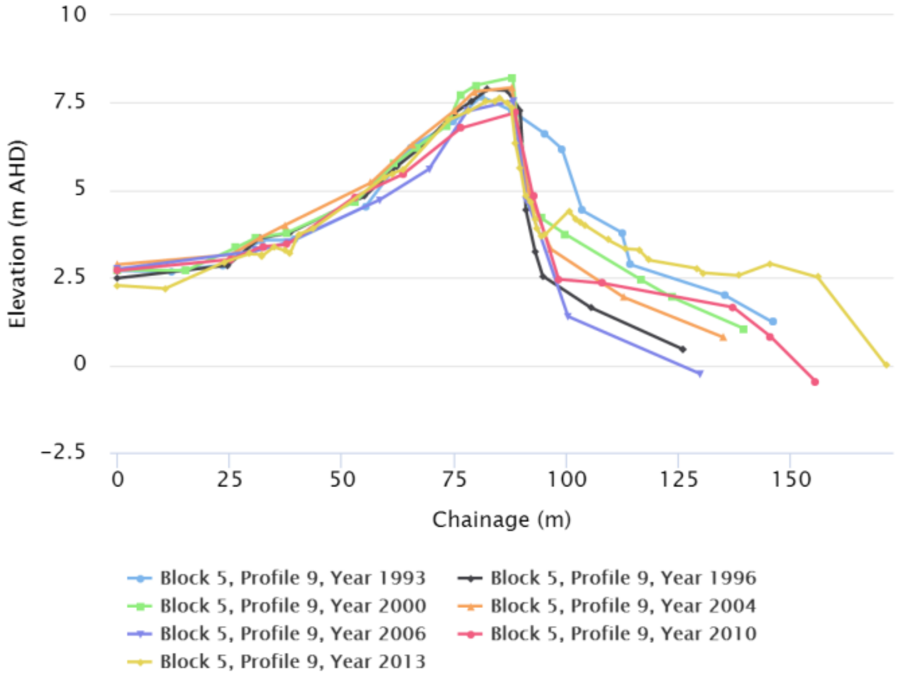

Figure 2: Profile plots post 1990 at Wooli Beach

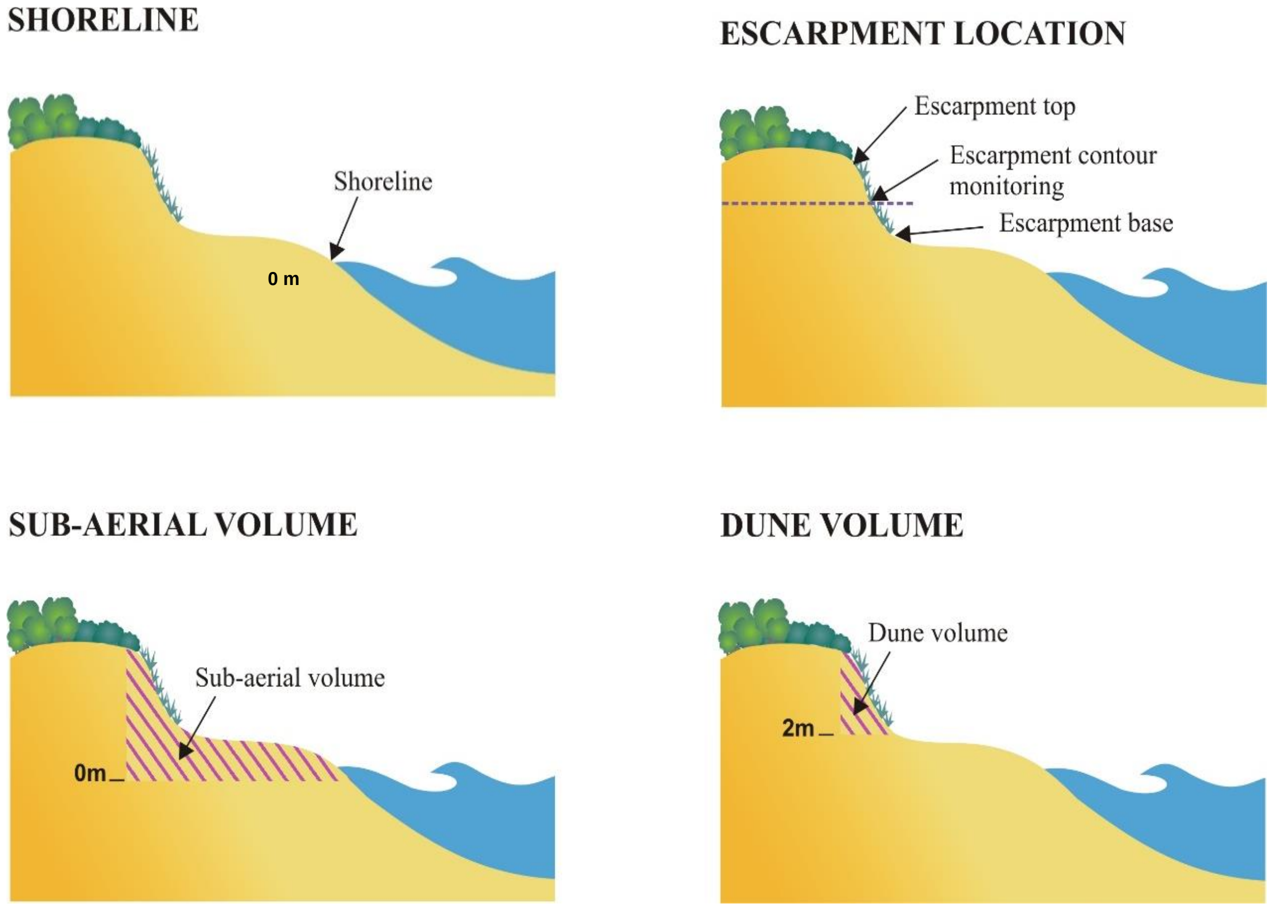

Figure 3: Coastal Change Trend Indicators - from Hanslow 2007 [4]. These underpin the analysis tools provided as an online tool within the NSW Beach Profile Database.

seaward points available in the observed data, unless it exceeds the maximum or minimum beach slope. To minimise errors and/or exclude changes associated with non-beach related process it is necessary to adjust the landward limit for the volume calculations on a profile by profile basis.

5.1.4 Applications to Coastline Monitoring
The two timeseries calculation tools are provide as a simple estimate of beach erosion trends. Hanslow [4] evaluated six trend indicators that can be used to evaluate beach change. Four of these methods (shown in Figure 3) can be extracted using the tools available in the *NSW Beach Profile Database*:

1. Position of the shoreline – while Hanslow [4] was able to directly assess the position of the shoreline from imagery, using the 0 m AHD contour as a proxy for shoreline is possible using the database contour tool;
2. Escarpment monitoring contour – this can be the bottom, top or face of the dune, which can be chosen based of the visualisation of the profile data. Using the contour tool, this will typically mean selecting an elevation between 3 – 6 m AHD;
3. Sub-aerial volume – this utilises the volume tool above 0 m AHD. An appropriate landward limit to exclude impacts of vegetation change and man-made structures must be chosen;
4. Dune volume – using the volume tool above the point where the beach face intercepts the dune face, typically volume above 2 – 4 m AHD.

The remaining two indicators, the vegetation line and the high water line, require visual inspection of the images, and cannot be extracted via the online toolbox.

6. Example Application: Wooli Beach

Wooli Beach is located on the north coast of NSW, and is part of the Clarence Valley Council. It is one of the coastal erosion hot spots identified by NSW OEH [6]. This section describes the use of the online toolbox to examine ongoing trends at three profiles at Wooli Beach.

Figure 5: Wooli Beach Profile Locations. The profiles are spaced at approximately 50 m apart, extend along the entire beach and are shore normal

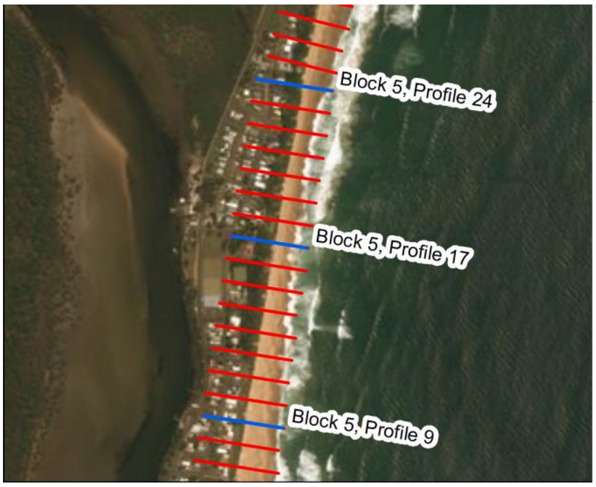

Figure 4: Profiles used in this analysis in front of infrastructure are highlighted in blue

Wooli has been extensively surveyed as part of the photogrammetry database collected by OEH. The beach has been imaged and analysed at most profiles on 13 occasions between 1942 – 2013, along the entire length of the beach. Shore normal profiles are spaced approximately every 50 m along the beach, shown in Figure 4. Figure 5 highlights the three profiles chosen for this example, however it should be noted that as many profiles as required can be analysed together. These figures were created using a standard GIS system, by importing shapefiles directly downloaded from the online *NSW Beach Profile Database*.

Figure 6 shows results of analysis undertaken using the online database. Note that the surveys at Wooli did not generally extend seaward to 0 m AHD, so this shoreline position cannot be determined. However, an escarpment monitoring contour, sub-aerial volume and dune volume were calculated. The online beach profile analysis toolbox allows rapid analysis of all the chosen profiles, with Figure 6 displaying the graphical results and Table 3 tabulating the regression coefficients derived from the online toolbox.

Table 3: Regression coefficients for the analysed profiles

Monitoring Trend	Profile	Slope	r^2
Escarpment Monitoring (6 m AHD) (m/year)	Block 5, Profile 9	-0.41	0.93
	Block 5, Profile 17	-0.22	0.85
	Block 5, Profile 24	-0.17	0.52
Sub Aerial Volume (above 0 m AHD) (m^3/m/year)	Block 5, Profile 9	-1.64	0.14
	Block 5, Profile 17	-0.7	0.03
	Block 5, Profile 24	-2.28	0.31
Dune Volume (above 2.5 m AHD) (m^3/m/year)	Block 5, Profile 9	-1.39	0.55
	Block 5, Profile 17	-0.76	0.26
	Block 5, Profile 24	-1.3	0.66

7. Conclusions

The *NSW Beach Profile Database* is designed to provide a freely available, online resource enabling unrestricted access to existing and future survey data held by the NSW Office of Environment and Heritage extending along the entire State coastline. Its purpose is aimed at helping the community at all levels – from internal government uses, consulting companies, research and as an educational resource. Data can be reviewed and analysed by anyone, however to download data users must first create a free log in.

Due to the extensive and variable nature of the available survey data that is now incorporated within the *NSW Beach Profile Database*, there are likely to be issues that arise with some specific datasets, particularly the very early photogrammetry which tends to have low accuracy. The interface includes the capability for users to flag data that they believe may have quality issues. Accepted quality flags will be visible to all future visitors to the site, and it is anticipated that a mechanism will be developed for these specific data to be reviewed internally, to assess their continued suitability for display within the toolbox.

Figure 6: Toolbox results for three profiles at Wooli. From top to bottom: escarpment monitoring contour (6 m AHD), sub-aerial beach volume (above 0 m AHD) and dune volume (above 2.5 m AHD).

Importantly, the database will continue to grow as NSW OEH undertakes further photogrammetric analysis and receive additional beach profile survey data. This statewide NSW beach profile dataset is generally the longest large-scale coastline surveying that is available for the great majority of NSW beaches. Given the cultural, economic and environmental importance of coastal regions in NSW, this information will continue to be a key resource used to evaluate variability and long-term trends of erosion and accretion along the NSW coastline. The *NSW Beach Profile Database* provides new and unprecedented public access to this resource. And by providing a range of beach profile visualisation and standard coastal engineering analyses tools, it is anticipated to improve the accessibility and efficiency of site-specific studies.

8. References

[9] Apache HTTP Server Project, Version 2.4. Available at https://httpd.apache.org/

[2] Django (Version 1.10) [Computer Software]. (2016). Retrieved from https://djangoproject.com.

[3] Evans, P. and Hanslow, D., 1996. Take a Long Line–Risk and Reality in Coastal Hazard Assessment. In Proceedings of the 6th NSW Coastal Conference, Ulladulla.

[4] Hanslow, D. J., 2007. "Beach erosion trend measurement: a comparison of trend indicators." Journal of Coastal Research 50 588-593.

[5] Hanslow, DJ, Clout, R, Evans, P and Coates, B (1997) MONITORING COASTAL CHANGE USING PHOTOGRAMMETRY Proceedings of the Institute of Australian Geographers and New Zealand Geographical Society Second Joint Conference, Hobart, Australia, 1997, Department of Geography, The University of Waikato

[6] OEH (2011) Coastal erosion 'hot spots' available from http://www.environment.nsw.gov.au/coasts/coasthotspots.htm

[7] Python Software Foundation. Python Language Reference, version 3.5. Available at http://www.python.org

[8] Sallenger Jr, A.H., Krabill, W.B., Swift, R.N., Brock, J., List, J., Hansen, M., Holman, R.A., Manizade, S., Sontag, J., Meredith, A. and Morgan, K., 2003. Evaluation of airborne topographic lidar for quantifying beach changes. Journal of Coastal Research, pp.125-133.

[9] Turner, I.L., Harley, M.D. and Drummond, C.D., 2016. UAVs for coastal surveying. Coastal Engineering, 114, pp.19-24.

[10] Watson, P.J. and Lord, D.B., 2001. Coastal Hazard Definition for Planning Purposes Using Photogrammetric Techniques. In 15th Australasian Coastal and Ocean Engineering Conference, September, pp81-88.