An Australian Government Initiative

Funded through the Murray–Darling Water and Environment Research Program

Australia's National Science Agency

Description and metadata for two-monthly maximum flood water extent and depth for the Murray-Darling Basin

Report T2.7.4

Murray—Darling Water and Environment Research Program

Project RQ7 Enhancing floodplain inundation and volume prediction to support environmental watering and water resources planning

Jin Teng, Catherine Ticehurst, Dave Penton, Ang Yang, Steve Marvanek, Fathaha Khanam, Jai Vaze, Cherry Mateo

6 March 2024

Supported through funding from the Australian Government Murray–Darling Water and Environment Research Program

Citation

Teng J, Ticehurst C, Penton D, Yang A, Marvanek S, Khanam F, Vaze J and Mateo C (2023) Description and metadata for two-monthly maximum flood water extent and depth for the Murray-Darling Basin. Report T2.7.4. CSIRO, Australia.

Copyright

Important disclaimer

Foreword

This report is a technical note that describes two datasets that were produced in the second year of the RQ7 – Enhancing floodplain inundation and volume prediction research, which is part of the Murray-Darling Water and Research Program (MD-WERP). The datasets cover the period from 1988 to 2022, providing a comprehensive view of the changing water extent, depth and volume across the entire Murray-Darling Basin. This report consists of two parts, corresponding to the two datasets: Maximum two-monthly surface water extent for MDB from MIM and WOFS and two-monthly maximum flood water extent and depth for the Murray-Darling Basin.

Contents

Figures

Acknowledgments

This work is carried out in CSIRO Land and Water as part of the Murray–Darling Water and Environment Research Program (MD-WERP). The Murray–Darling Water and Environment Research Program is an Australian Government initiative to strengthen scientific knowledge of the Murray–Darling Basin. It is designed to help inform water and environment management decisions which will improve outcomes for the Basin and its communities. Four priority themes have been identified as the focus of the strategic research: Climate Adaptation, Hydrology, Environmental Outcomes, and Social, Economic and Cultural Outcomes. Research Question 7 (RQ7) – Enhancing floodplain inundation and volume prediction to support environmental watering and water resources planning – is one of the research projects in the Hydrology theme.

The authors thank Francis Chiew, David Post from CSIRO; Charlotte Dennis, Alistair Korn from Murray–Darling Basin Authority for project management, useful discussions and/or coordinating access to data.

The authors pay respect to the Traditional Owners and their Nations of the Murray−Darling Basin. We acknowledge their deep cultural, social, environmental, spiritual, and economic connection to their lands and waters.

Executive summary

The Research Question 7 (RQ7) research aims to build on the capacity and models from previous research and develop a model that is suitable for systematic management and scenario planning, which requires multiple modelling runs across large areas, and over long simulation periods. The research will improve the prediction of flood inundation extent, depth and duration, and floodplain volumes.

During the second year of our research, we have generated two long-term, basin-wide datasets for the Murray-Darling Basin (MDB) covering the period from 1988 to 2022: two-monthly maximum surface water extent and two-monthly maximum water depth. These datasets provide a comprehensive view of the changing water extent, depth, and volume across the entire Murray-Darling Basin, and will be valuable for the development and validation of the RQ7 model. The datasets have been made available on the CSIRO Data Access Portal (https://data.csiro.au/). This report contains a detailed description and metadata for the datasets.

The main users of the project outputs will be the Murray—Darling Basin Authority (MDBA), Basin States, the Commonwealth Environmental Water Office (CEWO) and hydrological and environmental researchers and consultants. The knowledge, data and tools developed in this project will enhance floodplain inundation and volume prediction and modelling under current and future climates and under different management options to inform environmental watering and water resources planning and adaptation.

Part I Maximum two-monthly surface water extent for MDB from MIM and WOfS

Content adapted from Ticehurst et al. (2021)

1 Introduction

Accurately mapping surface water extent is critical in estimating water volume and monitoring changes for effective water management. This is essential for human consumption, agricultural use, and maintaining the ecological health of wetlands and rivers. With a growing population and changing climate, the need for precise information on available water is more critical than ever, especially in Australia, which is the driest inhabited continent in the world and continues to experience large interannual variability between dry and wet periods.

Ground observations of surface water extent can provide valuable information but are not always available, and large-scale synopses of current and historical water extent through gauging stations and high water marks are hard to obtain. Remote sensing technologies offer an affordable means of capturing surface water extent with reasonable spatial and temporal coverage suitable for water monitoring. The Landsat satellite series' spatial resolution (30m) makes it suitable for capturing (subject to cloud cover) much of the fine spatial detail of a large river basin. The Landsat archive provides data dating back to 1987 for the thematic mapper series. Each Landsat satellite returns to the same point every 16 days. Given there can be overlap in the operation of one satellite with its replacement, the temporal frequency varies through history and can be greater than 16 days.

The Water Observations from Space (WOfS) dataset is generated by Geoscience Australia and available through Digital Earth Australia (Mueller et al., 2016). WOfS uses a decision tree approach based on a selection of Landsat spectral bands and indices, as well as ancillary products (including topography and hydrology layers) to constrain water extent to likely areas. Individual WOfS images of surface water extent, along with summary statistics from the 1980s to the present, are available for Australia for the entire Landsat archive. WOfS provides a conservative estimate of surface water extent, making it a robust product, but it is more likely to underestimate than overestimate water extent (Sims et al. 2016).

A multi-index method (MIM) has been developed for mapping surface water extent within the Murray-Darling Basin (Ticehurst et al., 2022). It is based on existing indices, such as the modified Normalised Difference Water Index (mNDWI; Xu 2006), Fisher's water index (FWI; Fisher et al. 2016), and the Tasseled Cap Wetness Index (TCW; Dunn et al. 2019), which are already used for mapping surface water extent. Each index is applied in the area where it performs best, and the resulting rule-set uses NDWI>–0.3 to map water in major perennial rivers, TCW>-0.035 to map water in wetlands, and the maximum of NDWI>0 and FWI>0.63 for mapping water in the remaining areas. Based on 440 validation plots in the Murray-Darling Basin, this resulted in an overall balanced accuracy of 92.7%.

The combined MIM and WOfS surface water extent dataset described here covers Murray-Darling Basin (MDB) (shown in Figure 1), which is situated in southeastern Australia and spans an area of more than one million square kilometres. It encompasses over 40,000 kilometres of major rivers and has over 30,000 wetlands, with 16 of them having international significance. Additionally, the MDB is responsible for approximately 40% of Australia's agricultural production. The northern region of the MDB is mainly composed of unregulated ephemeral rivers and streams, whereas the southern region is mostly regulated rivers with several significant water storages.

The MIM_WOfS_max product can be used to explore long-term and seasonal trends across the basin as well as any area of interest within the basin.

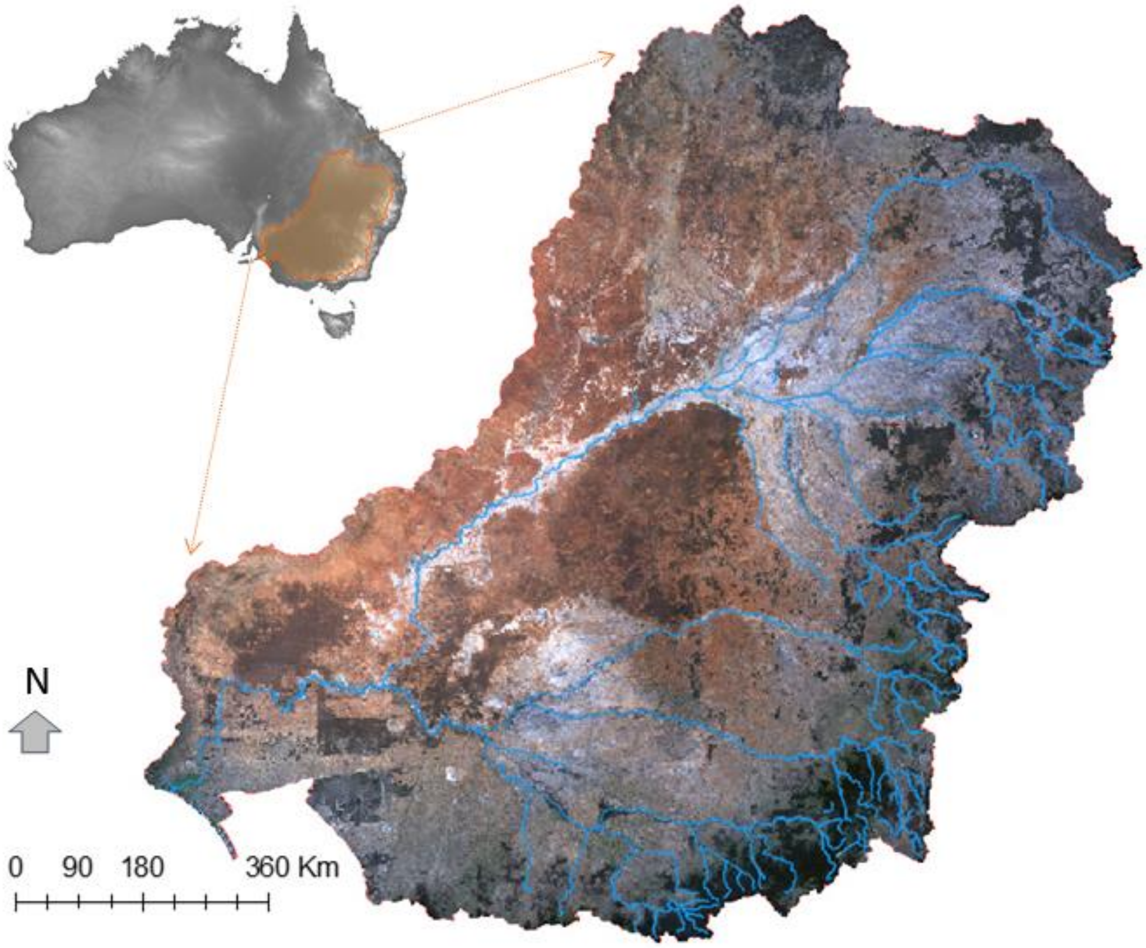

Figure 1 Location of the Murray-Darling Basin within Australia. Blue lines show perennial rivers overlaid on Landsat 8 geo-median image from Digital Earth Australia (used with permission from Ticehurst et al., 2021).

The data can be accessed from the CSIRO Data Access Portal (https://doi.org/10.25919/s7c2-hc39) and can be cited as:

Ticehurst, Catherine; Penton, Dave; Teng, Jin; Sengupta, Ashmita (2022): Maximum two-monthly surface water extent for MDB from MIM and WOFS - Version 2. v2. CSIRO. Data Collection. https://doi.org/10.25919/s7c2-hc39

2 Metadata

Location	**https://doi.org/10.25919/s7c2-hc39**
File convention	/UPDATE/WATER/MIM_WOFS_V2_yyyy_mm_WATER.tif
Format	TIFF
Size	357.98 GB
Temporal	Every two months
Data type	integer
Values	Pixel values are: ‘0’ for mNDWI>0, ‘1’ for FWI>0.63, ‘2’ for mNDWI>–0.3, ‘3’ for TCW>–0.035, ‘4’ for mNDWI>–0.15, ‘5’ for TCW>–0.01, ‘6’ = snow zone mask, ‘7’ = steep terrain mask, ‘8’ = WOFS, ‘9’ = manually masked due to high cloud cover or artefacts, ‘10’ = forest mask (excluding floodplains), ‘11’ = mask of sloped terrain where erroneous water is commonly mapped, ‘255’ = no data (this is for pixels outside the MDB)..
Projection	WGS84; ESPG 4326
Resolution	30 m
Extent	**West** 138.56 **East** 152.50 **North** -24.57 **South** -37.68 Murray-Darling Basin

3 Processing steps

We extracted and processed Landsat data from 1988 to 2022 using Digital Earth Australia (DEA) as analysis-ready Landsat surface reflectance. The DEA provided WOfS water maps as well. The MDB covers 62 individual Landsat path/row scenes.

We processed the data on the Earth Analytics Science and Innovation (EASI) platform, which is a new high-performance data analytics platform developed by CSIRO that 'turbo-charges' the capacity to process and integrate huge amounts of Earth Observation (EO) data with other geospatial information and models. The method was developed using Jupyter notebooks and parallel processed using Elastic Compute Cloud (EC2) provided by Amazon Web Services (AWS).

The extraction method for Landsat surface reflectance and WOfS differed due to the different way cloud masking is applied. Landsat surface reflectance uses the standard Fmask layer, while WOfS uses Fmask and the automatic cloud cover assessment method to further reduce the chance of remnant cloud or cloud shadow in the imagery.

For WOfS, we extracted images within a degree tile covering the MDB for every two months and produced maximum water extent maps. The MIM water images require six Landsat bands. We extracted these bands using DEA's load_ard function as third-of-a-degree tiles, which were then merged. The load_ard function has an option of specifying the maximum percentage of cloud cover allowed to be extracted from images within the defined extent, and a threshold of 20% cloud cover was chosen.

All of the MIM two-monthly water images were visually inspected for remaining artifacts, which were manually masked from the image. A snow zone mask was created for the alpine region and applied to the two-monthly images for the colder months. Three large lakes exist within the snow zone, which were not included in the snow mask. They were inspected to make sure they appeared to be free of snow and only manually masked if needed. A forest mask was used (from Potapov et al. 2021) to remove tall vegetation (excluding those on floodplains) as these areas are sometimes misclassified as water. An additional mask was created to remove areas in the uplands that were often erroneously identified as water.

To minimize null values and maximize surface water extent for every two months, the maximum water extent was calculated from the MIM and WOfS products. The 35 years of this new two-monthly product (called the MIM_WOfS_max) were combined to create an image of the percentage of time that a pixel is wet.

Part II Two-monthly Maximum Flood Water Depth Spatial Timeseries for the MDB

Content adapted from Penton et al. (2023)

1 Introduction

This dataset was produced for researchers and stakeholders seeking to understand the changing flood patterns in the Murray Darling Basin (MDB) in Australia. The consistent time series of water depth maps cover the entire basin and were historically difficult to access on a large scale. These datasets are crucial for comprehending the impact of changing flood extent and volume on the MDB's floodplain ecosystems. The dataset spans every two-month period from 1988 to 2022 and was created using remotely sensed imagery and flood perimeter models at approximately 30 m spatial resolution. The resulting comprehensive picture of maximum observed inundation depth across the MDB is best suited to system-wide analysis, but it may also be useful for investigating the flooding history at specific points in the system. We validated the dataset against 13 hydrodynamic models for different parts of the MDB, which yielded a mean absolute error of 0.49 m, demonstrating reasonable accuracy and reliability. We are providing the dataset, visualization tools, and examples to support ongoing research.

We utilized FwDET (Cohen et al., 2018) to estimate flood water depth and evaluated product accuracy by comparing it to hydrodynamic models for select floodplains. The resulting product offers spatial layers that depict the maximum observed surface water extent and water depth within each two-month period across the Murray-Darling Basin (MDB) at approximately 30-metre resolution from 1988 to December 2022.

This dataset can be instrumental in examining the relationship between flooding and ecological functions. It is most suitable for analysing the MDB as a whole over prolonged periods. For instance, researchers can use the dataset to investigate the physical and biological connectivity of the floodplain and how it has evolved over time. The dataset is also ideal for developing empirical relationships between flooding and ecosystem processes. While it may also be beneficial for those interested in the flood history of specific areas within the river system, it is important to verify its accuracy using local data. Figure 2 shows an example of the maximum floodwater depth computed over 35 years. Linear features running in an approximate north-south direction are visible in the image, which are caused by noise resulting from the Landsat 5 images' swath edge (during its later years of operation) where pixels are mistakenly classified as water.

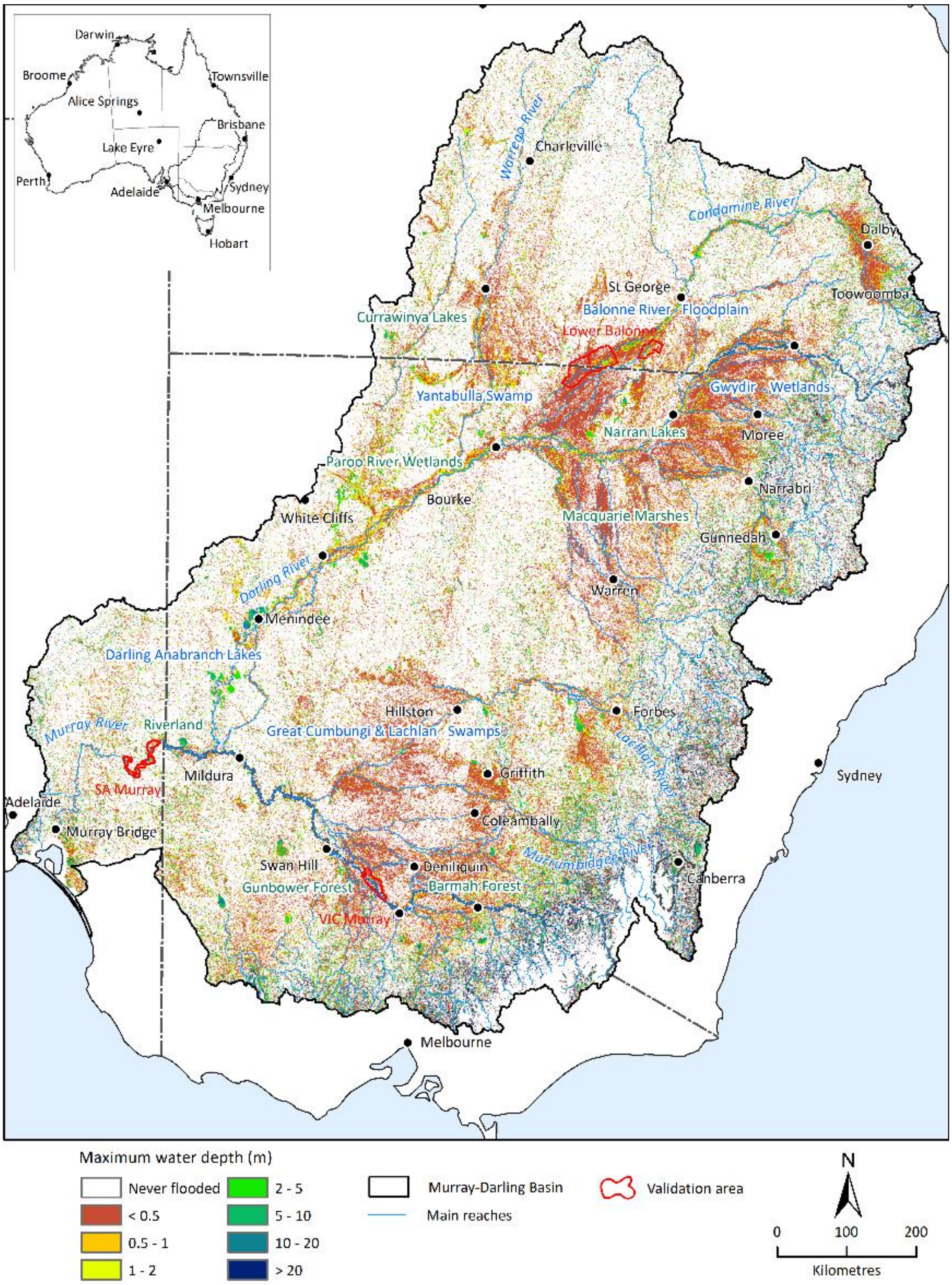

Figure 2 Maximum floodwater depth. The maximum floodwater depth for MDB calculated from the two-monthly floodwater depth dataset (used with permission from Penton et al., 2023).

The data can be accessed from the CSIRO Data Access Portal (https://doi.org/10.25919/c5ab-h019) and can be cited as:

Teng, Jin; Penton, Dave; Ticehurst, Catherine; Sengupta, Ashmita; Freebairn, Andrew; Marvanek, Steve; King, Darran; Pollino, Carmel (2023): Two-monthly Maximum Flood Water Depth Spatial Timeseries for the MDB. v20. CSIRO. Data Collection. https://doi.org/10.25919/c5ab-h019.

2 Metadata

Location	**https://doi.org/10.25919/c5ab-h019**
File convention	MDB_Water_Depth_v3.6_4326\ FwDET_v3_TPS_yyyy_mm.tif
Format	Cloud Optimised GeoTIFF (COG)
Size	23.19 GB
Temporal	Every two months
Data type	uint16.
Unit	millimetre
Values	The maximum depth is 65534 mm; minimum water depth is 1 mm; pixel value ‘0’ represents dry land; and ‘65535 ‘represents no-data.
Projection	WGS84; ESPG 4326
Resolution	30 m
Extent	**West** 138.56 **East** 152.50 **North** -24.57 **South** -37.68 Murray-Darling Basin

3 Processing steps

The workflow that produced the flood depth products using the FwDET algorithm is depicted in Figure 3. The following are the steps involved in building the flood water depth product for the MDB:

The process of building the flood water depth product for the MDB involves several steps, as shown in Figure 3. Firstly, input data processing involves acquiring two products: two-monthly maximum water surface extent from Landsat and high-resolution digital elevation model (DEM) combined from data sources. This data is split into 23 regions for processing.

Secondly, the FwDET algorithm v2 (Teng et al., 2022) is used to identify the surface water elevation at the boundary (perimeter) of inundated areas. The perimeter water surface levels are then interpolated across inundated areas to provide continuous surface water levels. The depth is calculated by subtracting the DEM from the surface water levels and merging (recombining) across the MDB.

Finally, the resulting water depth rasters are archived and distributed through web services such as Web Mapping Service and a geospatial visualisation platform for point-and-click visualisation of water depth across the floodplains of the MDB. These steps provide a valuable resource for researchers and stakeholders interested in understanding the changing flood patterns of the Murray Darling Basin, particularly in investigating links between flooding and ecological functions.

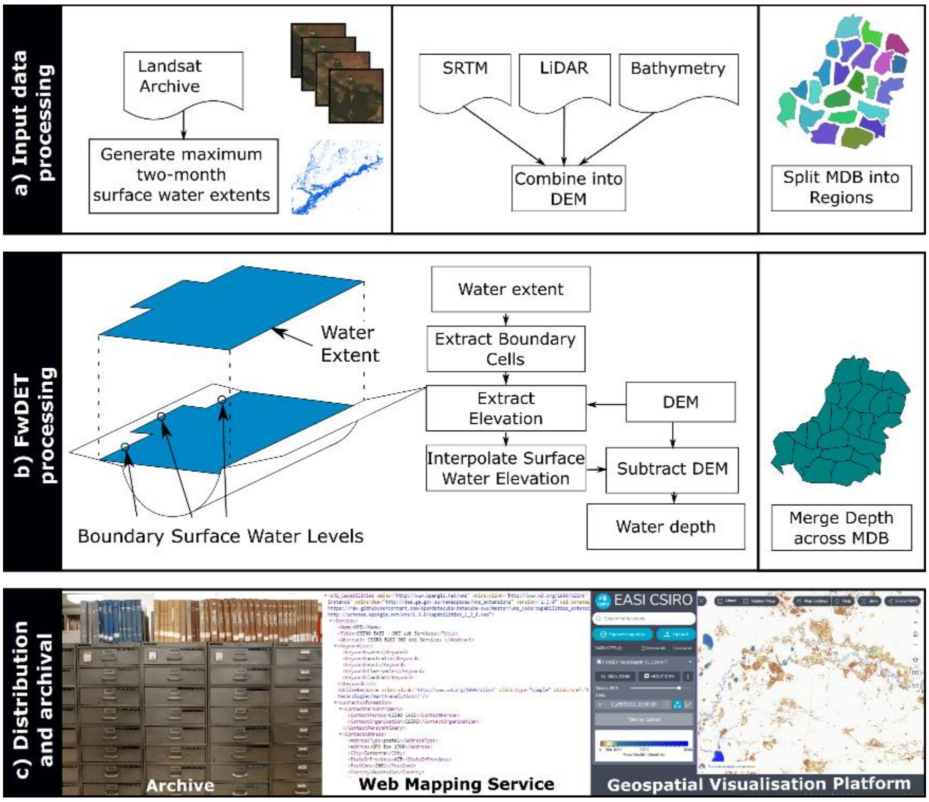

Figure 3 Steps involved in building flood water depth product for MDB (used with permission from Penton et al., 2023).

Acronyms

DAP: Data Access Portal

DEM: Digital Elevation Model

GA: Geoscience Australia

LiDAR: Light Detection and Ranging

MDB: Murray-Darling Basin

MDBA: Murray-Darling Basin Authority

RQ7: Research Question 7 – Enhancing Floodplain Inundation and Volume Prediction to Support Environmental Watering and Water Resources Planning

SRTM: Shuttle Radar Topography Mission

References

Cohen S, Brakenridge GR, Kettner A, Bates B, Nelson J, McDonald R, Huang YF, Munasinghe D, Zhang J (2018) Estimating Floodwater Depths from Flood Inundation Maps and Topography. Journal of the American Water Resources Association 54, 847–858.

Dunn B, Lymburner L, Newey V, Hicks A, Carey H (2019) Developing a tool for wetland characterisation using fractional cover, Tasseled Cap Wetness and Water Observations from Space. *IGARSS 2019 - 2019 IEEE International Geoscience and Remote Sensing Symposium*, 2019, pp. 6095-6097, doi: 10.1109/IGARSS.2019.8897806.

Fisher A, Flood N, Danaher T (2016) Comparing Landsat water index methods for automated water classification in eastern Australia. Remote Sensing of Environment, 175, 167-182, https://doi.org/10.1016/j.rse.2015.12.055.

Mueller N, Lewis A, Roberts D, Ring S, Melrose R, Sixsmith J, Lymburner L, McIntyre A, Tan P, Curnow S, Ip A (2016) Water observations from space: Mapping surface water from 25 years of Landsat imagery across Australia. Remote Sensing of Environment, 174, 341-352.

Penton D, Teng J, Ticehurst C, Marvanek S, Freebairn A, Mateo C, Vaze J, Yang A, Khanam F, Sengupta A, Pollino C (2023) The floodplain inundation history of the Murray-Darling Basin through two-monthly maximum water depth maps. Scientific Data, under review.

Potapov P, Li Z, Hernandez-Serna A, Tyukavina A, Hansen MC, Kommareddy A, Pickens A, Turubanova S, Tang H, Silva CE, Armston J, Dubayah R, Blair Jb, Hofton M (2021) Mapping and monitoring global forest canopy height through integration of GEDI and Landsat data. Remote Sensing of Environment, 253, https://doi.org/10.1016/j.rse.2020.112165.

Sims N, Anstee J, Barron O, Botha E, Lehmann E, Li L, McVicar T, Paget M, Ticehurst C, Van Niel T, Warren G (2016) Earth observation remote sensing. A technical report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resource Assessments. CSIRO, Australia.

Ticehurst C, Teng J, Sengupta A (2021) Generating two-monthly surface water images for the Murray-Darling Basin. MODSIM 2021 Keynote 421-427. https://www.mssanz.org.au/modsim2021/papers/G5/ticehurst.pdf.

Ticehurst C, Teng J, Sengupta A (2022) Development of a Multi-Index Method Based on Landsat Reflectance Data to Map Open Water in a Complex Environment. Remote Sensing, 14(5):1158. https://doi.org/10.3390/rs14051158.

Teng J, Penton DJ, Ticehurst C, Sengupta A, Freebairn A, Marvanek S, Vaze J, Gibbs M, Streeton N, Karim F(2022) A Comprehensive Assessment of Floodwater Depth

Estimation Models in Semiarid Regions. Water Resources Research 58, e2022WR032031.

Xu H (2006) Modification of normalised difference water index (NDWI) to enjance open water features in remotely sensed imagery. International Journal of Remote Sensing, 27, 3025-3033. doi: 10.1080/01431160600589179.

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

Contact us

1300 363 400
+61 3 9545 2176
csiroenquiries@csiro.au
www.csiro.au

For further information

Environment
Dr Jin Teng
+61 2 6218 3513
Jin.teng@csiro.au
csiro.au/en/about/people/business-units/land-and-water