Floodplain water harvesting in the Northern New South Wales Murray-Darling Basin

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Research · Communication · Policy

Contributors

This project was made possible with the support of the following groups and Individuals:

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Definitions & Acronyms

AHD	Australian Height Datum (metres)
BDL	Baseline Diversion Limit
Cap	The legislative requirement to limit surface water extractions to the level of development at 1 July 1994
DEM	Digital Elevation Model
DPIE	NSW Department of Planning, Industry and Environment
DPI – W	Department of Primary Industries – Water (predecessor to DPIE)
ESLT	Environmentally Sustainable Diversion Limit
LiDAR	Light Detection and Radar
MDBA	Murray-Darling Basin Authority
MDBC	Murray-Darling Basin Commission (predecessor to the MDBA)
MinCO	Murray-Darling Basin Ministerial Council
Plan limit	The annual average long-term extraction limit specified in NSW Water Sharing Plans
QGIS	Quantum Geographic Information System
Permanent storage	Storages designated to store floodplain water harvesting, fitted with a storage meter.
Rainfall Runoff Harvesting	Rainfall runoff refers to runoff from developed areas resulting from direct rainfall. It does not include flood water that has broken out from the banks of rivers and creeks.
SDL	Sustainable Diversion Limit
Tailwater drain	Trench or channel that collects runoff from an irrigation field
Temporary storage	Surge areas, field storage and purpose-built dams that are used to hold water temporarily.
WOfS	Water Observations from Space

Summary

The Murray-Darling Basin Cap (Cap) is one of the foundations of the water reforms in the Murray-Darling Basin. The Cap limits extractions to the level of development in place on 1 July 1994.

For more than 25 years floodplain water harvesting has been recognised by governments as a major threat to the Cap, the environment, downstream communities and downstream entitlements.

The NSW Floodplain Harvesting Policy defines floodplain harvesting as:

> *…the collection, extraction or impoundment of water flowing across floodplains, including rainfall runoff and overbank flow,*

and states that for the purposes of the policy:

> *…'floodplain' means any area of land designated as a floodplain under the Water Management Act 2000 or the Water Act 1912,*

Floodplain water harvesting is a legislated form of extraction under the Cap. However, it has never been regulated, measured or controlled in NSW, nor accounted for under the Cap.

The NSW Government acknowledges that there has been a growth in take by floodplain water harvesting. The government intends to license it based on on-farm storage capacity by July 2021, claiming that the licensed volumes will reduce extractions to the Cap.

There is a strong correlation between the capacity of on-farm storages and the amount of floodplain water harvesting.

This project mapped on-farm storages and calculated their capacity in the five northern NSW valleys where floodplain water harvesting licences will be issued. The capacity of on-farm storages increased by 142% (or 2.4 times) between 1994 and 2020, from 574 gigalitres in 1993/94, to 1,395 gigalitres in 2020. The number of on-farm storages has increased from 400 in 1988, to 1,833 in 2020.

Background

When the major rivers of the Northern Murray-Darling Basin flow onto their lower floodplains they break up into thousands of smaller rivers, creeks, cowals, warrambools, flood runners and billabongs. One of these is the designated river. The floodplains of the Northern Basin make up a vast interconnected network of these streams. Floodplain water harvesting is the take of water from these floodplains.

Despite it being a large proportion of water taken for irrigation in the NSW part of the Northern Murray-Darling Basin it has never been regulated, measured or reported.

The NSW government intends to license and regulate floodplain water harvesting by July 2021.[i] Extraction will be accounted for under a water access licence, basic landholder right or licence exemption, ensuring that it is consistent with the *Water Management Act 2000*.[ii]

The amount of water taken by floodplain water harvesting will be measured and the volume distributed, after it is licensed. Owners of floodplain water harvesting licences will be able to be compensated for these new licences, should they be reduced in future.[iii]

Floodplain water harvesting has never been licensed, measured or monitored in NSW. On the 24th of March 2020, Helen Dalton, the NSW Member for Murray, asked Melinda Pavey, the Minister for Water, Property and Housing, in the NSW Parliament:

> *What has been the volume of water extracted through floodplain harvesting in each financial year between 1993-94 and 2018-19?*[iv]

The Minister replied:

> *There is currently very limited data on the volume of water that has been extracted through floodplain harvesting in New South Wales because such volumes have not been required to be reported by landholders.*[v]

At a public meeting in Dubbo on 16th March 2018 an officer of the NSW water department acknowledged that the volume of water taken by floodplain water harvesting had been:

> *...grossly underestimated, ...there is currently no monitoring of floodplain harvesting diversions.*[vi]

This report:

- Provides a background and summary of the NSW floodplain water harvesting policy and its implementation,
- Reviews research and reports related to floodplain water harvesting,

- Provides a map of on-farm storages on the floodplains of the NSW part of the Northern Murray-Darling Basin and the capacity of those storages.

Floodplain water harvesting policy

The NSW Floodplain Harvesting Policy states that:

> *For the purposes of this policy, 'floodplain' means any area of land designated as a floodplain under the WM Act* [Water Management Act 2000] *or the Water Act 1912. The policy applies to floodplain harvesting activities on properties where all or part of that property lies within the designated floodplain (p4).*[vii]

The policy defines floodplain harvesting as:

> *...the collection, extraction or impoundment of water flowing across floodplains, including rainfall runoff and overbank flow, but excluding the taking of:*
> - *water under a water access licence that is not a floodplain harvesting access licence*
> - *water under a basic landholder right, including water taken under a harvestable right*
> - *water under an applicable water access licence exemption under the WM Act*
> - *used irrigation water (p 4).*[viii]

For more than 25 years governments have known that floodplain water harvesting is a risk to downstream water supplies.

In 1995, the Murray-Darling Basin Ministerial Council (MinCo) agreed to place a Cap on extractions at the 1993/94 level of development. NSW is obliged to keep surface water take under the Cap.[ix]

The Murray-Darling Basin Commission (MDBC) stated that:

> *floodplain waterharvesting is perceived as an issue of Basin wide concern. A number of consultative management planning exercises are presently underway to examine and address overall floodplain management issues including floodplain harvesting.*[x]

However, floodplain water harvesting was not initially included in Cap. Governments intended to deal with it later.[xi]

In 1995, a report to MinCo stated:

> *the capacity of on-farm storage on irrigation properties is the key factor determining how much use an irrigator can make of unregulated and off-allocation flows. In the north of the Basin the capacity of on-farm storages has more than doubled over the last five years to a value of 1,150 GL.*[xii]

In 2000 the Murray-Darling Basin Commission undertook a review of the operation of the Cap. It identified that not including floodplain water harvesting within the Cap was creating inequity between water users:

> *there are several more recently identified equity issues (floodplain and overland flows and diversions, farm dams and tree plantations) also requiring attention.*[xiii]

The Murray-Darling Basin Ministerial Council agreed to all the recommendations in the report, including that:

> *diversions from floodplain and overland flows be included in Cap accounting arrangements as a matter of priority.*[xiv]

The recommendation has not been implemented. Floodplain water harvesting has not been measured or licensed.

In about 2003, a Policy Advice from the NSW Government to Water Management Committees said:

> *The Water Act 1912 provided powers to license floodplain harvesting. However this was never applied as there was generally no requirement to restrict total overall water extractions or off- allocation diversions. Harvested floodplain water has been treated as a freely available bonus to a farmer's licensed entitlement.*[xv]

This 'freely available bonus' has grown to a considerable proportion of total take, as explained by a Senior Department of Planning, Industry and Environment (DPIE) official:

> *...floodplain harvesting in the northern basin accounts for approximately 25% of all surface water diversions permitted under WSPs and the Basin Plan...*[xvi]

In 2003 the Murray-Darling Basin Commission published a review of threats to flows in the Murray River. The threats identified were climate change, re-afforestation, groundwater extraction, return flows, farm dams, re-growth after bushfires, industry change and water trade. That work concluded:

> *the estimated impact on future flows, resulting from farm dam construction, based on the work of the MDBC, was found to be very high (1,000 to 3,000 gigalitres/annum) potentially greater than the combination of all other impacts.*[xvii]

In 2004, the National Water Initiative (NWI) identified the risk of growth in farm dams and floodplain water harvesting as potential impacts on water availability:

> *The Parties recognise that…land use change activities have potential to intercept significant volumes of surface and/or ground water now and in the future. Examples of such activities that are of concern, many of which are currently undertaken without a water access entitlement, include;*
>
> *i) farm dams and bores;*
> *ii) intercepting and storing of overland flows; and*
> *iii) large-scale plantation forestry.*
>
> *The Parties also recognise that if these activities are not subject to some form of planning and regulation, they present a risk to the future integrity of water access entitlements and the achievement of environmental objectives for water systems.*[xviii]

After signing the NWI, governments undertook a large body of work relating to the quantification of risks, including the growth of on-farm storages and floodplain harvesting.

In 2007 a report commissioned by the Murray-Darling Basin Commission noted:

> *More recently, there has been major private investment in large storages on irrigation farms. The total volume of these storages now rivals that of the headwaters dams, and they capture much of the water that enters the Basin's rivers downstream of the dams. This feature of water infrastructure in the Darling Basin sets it apart from the Murray.*[xix]

In 2010 a report under that program observed:

> *In 1995, the Murray–Darling Basin Ministerial Council agreed to place a Cap on diversions. Although in principle this Cap includes floodplain harvesting, it was not a focus in the initial policy reforms. Landholders sought to quickly install floodplain storages before moratoriums were put in place. Governments have moved in response to this trend, but the response time between on-ground issues and respective government policy has allowed considerable development to proceed in the meantime.*[xx]

Despite growth in farm dams being identified as a risk, governments were instead encouraging the construction of farm dams:

> *With the availability of laser-levelling, and NSW water licence conditions that require the irrigator to dispose of excess irrigation water (tailwater) on-farm (since such water typically contains pesticides and nutrients), irrigators have been encouraged to lay out farms so that both the irrigation tailwater and rainfall runoff from cropped areas drains back to central points for pumping into on-farm storages. With increases in developed areas for more cropping, and to allow appropriate rotation of land, the potential for harvesting rainfall runoff has also grown (Stazic 2016).* [xxi,xxii]

In 2010, the MDBA published the *Guide to the proposed Basin Plan*. The Guide stated that floodplain water harvesting estimates were included in SDL volumes, whilst acknowledging that estimates of floodplain water harvesting were not as accurate as estimates of water extracted from rivers and streams.[xxiii]

Small volumes of floodplain water harvesting were included in the Basin Plan (2012), (refer Table 2). Floodplain water harvesting volumes were not revised in the subsequent amendment to the Basin Plan in 2018.

On-farm storages and floodplain water harvesting

In the absence of data about take by floodplain water harvesting, NSW has had to estimate take by other means. DPIE explains its approach:

> *…we…used a capability assessment to consider the physical infrastructure used for floodplain harvesting and also the opportunity irrigators may have to access floodplain flows based on their location and climatic variability.*[xxiv]

DPIE identified a close relationship between floodplain water harvesting and the capacity to store water:

> *The volumetric capacity of on-farm storages is an essential piece of information to determine floodplain harvesting entitlements.*[xxv]

> *We identified at an early stage that floodplain harvesting results are very sensitive to on farm storage capacities.*[xxvi]

> *It is assumed that during large flood events most irrigators would plan to fill storages with floodplain harvesting instead…the model takes floodplain harvesting prior to other forms of available water.* [xxvii]

> *Harvesting of floodplain flows and rainfall runoff is primarily dependent on the infrastructure in place, such as channels, pumps and in particular the capacity to store the diverted water in on-farm storages.*[xxviii]

> *The ability to divert any overland flow that has accessed the property then depends on infrastructure developed to capture and store flood water, such as its intake capacity, and its on-farm storage capacity.*[xxix]

> *Within NSW, the practices of floodplain harvesting and rainfall runoff harvesting have been increasing since the early 1980s as irrigators in many parts of NSW have developed increasingly larger on-farm storages (Stazic et al., 2006). In general the practice of taking water in this way has bypassed the traditional water licensing system, the volumes taken have not been monitored and have been difficult to estimate.*[xxx]

The imperative to limit floodplain water harvesting is well documented in government reports and official meetings during the past 25 years, but until now the NSW Government has failed to act.

The NSW government floodplain water harvesting policy

The NSW Government is in the process of licensing floodplain water harvesting, 25 years after it was considered a matter of priority by the Murray-Darling Basin Ministerial Council. The current policy is to issue licenses at an historic level of extraction, infrastructure and works approvals by July 2021.

Licensing and take

DPIE has said that floodplain water harvesting licences will be based on how much water was taken at either the 1993/94 (Cap) or 1999/2000 level of development:

> *For most regulated rivers, it is specified as the lesser of:*
>
> - *the take of water that would occur with the infrastructure and management arrangements that existed in 1999–2000, combined with the water sharing plan rules, or*
> - *the take of water that would have occurred under the Murray–Darling Basin 'Cap' conditions.*[xxxi]

The Cap conditions are set out in Schedule E of the Murray-Darling Basin Agreement, and limit extractions to baseline conditions. Baseline conditions are defined as:

> *...the level of water resource development for rivers within the Murray-Darling Basin as at 30 June 1994 determined by reference to:*
>
> - *the infrastructure supplying water; and*
> - *the rules for allocating water and for operating water management systems applying; and*
> - *the operating efficiency of water management systems; and*

- *existing entitlements to take and use water and the extent to which those entitlements were used; and*
- *the trend in the level of demand for water within and from the Murray-Darling Basin.*[xxxii]

NSW proposed to license floodplain water harvesting at the lower of these levels of development by:

- assessing the capacity of on-farm storages at 3rd July 2008,
- assigning each landholder a notional share of the total volume of on-farm storages for each valley, and
- reducing the notional 2008 on-farm storage shares in proportion to the 1993/94 or 1999/2000 level of development.[xxxiii]

Temporary storages

Temporary storages are surge areas, sacrifice fields, or other areas where water from the floodplain or floodplain streams is stored temporarily. Some water enters the soil profile, some is transferred to a permanent storage and some evaporates.

The current policy is that water in a temporary storage is only measured and accounted as floodplain water harvest if it is transferred into a designated permanent on-farm storage. That is, water in a temporary storage will not be measured or accounted for as floodplain water harvest after floodplain water harvesting licences are issued.[xxxiv]

The capacity of temporary water storages is significant. For example, in 2017, DPIE estimated temporary storages in the Gwydir valley alone have a capacity of 400 gigalitres (345 gigalitres at 2013/14 and 55 gigalitres of future development).[xxxv, 1]

[1] Note, that DPIE has recently downgraded its assessment of temporary storages in the Gwydir valley from 400 gigalitres to 29 gigalitres. (NSW Department of Planning, Industry and Environment, 2021), https://www.industry.nsw.gov.au/__data/assets/pdf_file/0015/350205/model-build-report.pdf

Rainfall runoff

Under the New South Wales *Water Management Act 2000* [WMA, 2000], landholders can capture ten per cent of the average regional rainfall runoff on their land as their basic right, as well as 100 per cent of the average regional runoff from their irrigated land. These amounts are not included the floodplain water harvesting licence regime and are exempt from accounting against the floodplain water harvesting entitlement. DPIE explains:

> *In practical terms, Rainfall Allowance for each individual farm is calculated as a sum of maximum annual runoff generated from the developed for irrigation area and 10 per cent of LTA of annual runoff generated from a farm's non- irrigable area. Both values are generated using 2008/09 development and management conditions model.*[xxxvi]

DPIE has drafted a regulation to exempt rainfall runoff captured in tailwater drains from requiring a water access licence or a works approval.[xxxvii]

Accounting rules

DPIE has published proposed accounting rules for the NSW Border Rivers and the Gwydir valleys. They will be released for the Namoi, Macquarie/Wambuul and the Barwon-Darling/Baaka in coming months. The proposed accounting rules for floodplain water harvesting for the NSW Border Rivers and the Gwydir valleys are:

- Opening volume balances:
  - 100 per cent of the NSW Border Rivers regulated floodplain water harvesting licences,
  - 500 per cent of the Gwydir regulated floodplain water harvesting licences, and
  - 300 per cent of the Gwydir unregulated floodplain water harvesting licences.
- 100 per cent allocation on the first day of each water year thereafter,
- 500 per cent of the regulated floodplain water harvesting licence volume and 300 per cent for unregulated floodplain harvesting licence volume, as allowable take in any year, subject to account balances and
- unlimited carryover up to the annual take limit.[xxxviii] [xxxix]

DPIE proposes a high allowable annual take (500 per cent), to compensate for a relatively low face value of the proposed licences. The Chair of NSW Irrigators Council explained:

> *NSW Irrigators Council said the NSW Department of Planning, Industry and Environment had advised it "the general principle will be smaller licensed volume/higher carryover; larger licensed volume/less carryover".*[xl]

Table 1 below shows: the volume of floodplain water harvesting included in the Basin Plan; proposed and anticipated volumes to be licensed in NSW; and allowable annual take based on the proposed accounting rules. DPIE has proposed volumes for the Border Rivers and the Gwydir valleys. The anticipated volumes for the Namoi, Macquarie/Wambuul and the Barwon-Darling/Baaka are based on Government emails obtained under a Freedom of Information request.

Table 1: Basin Plan volumes, proposed floodplain water harvesting volumes, and allowable annual take

Valley	Basin Plan[xli] GL	DPEI proposed and anticipated volumes to be licensed GL	Allowable annual take[2] GL
NSW Border Rivers	3.0	38[xlii]	190
Gwydir	17.8	≈ 130[xliii]	≈ 630
Namoi	14.0	100[xliv]	500
Macquarie/ Wambuul	0	28[xlv]	140
Barwon-Darling/Baaka	11.5	25[xlvi]	125
Total	**46.3**	**≈ 321**	**≈ 1,585**

The proposed and anticipated floodplain water harvesting licence and allowable annual take volumes shown in Table 1 demonstrate a significant growth from 43.3 gigalitres under the Basin Plan to an approximate 321 gigalitres licence volume, which equates to approximately 1,585 gigalitres of allowable annual take, based on the proposed accounting rules.

[2] Assuming that the accounting rules to be proposed for the Namoi, Macquarie/Wambuul and the Barwon-Darling/Baaka are the same as the proposed rules for the Gwydir valley.

Estimates of floodplain water harvesting

It is well documented that past efforts to estimate floodplain water harvesting by governments have a large degree of uncertainty and are likely to be grossly underestimated.

Table 2 shows estimates of floodplain water harvesting in the Northern NSW Murray-Darling Basin.

Table 2: Estimates of floodplain harvesting extractions in the northern NSW Murray-Darling Basin

Author	NSW Border Rivers	Gwydir	Namoi	Macquarie /Wambuul	Barwon Darling /Baaka	Total
Bewsher Consulting[xlvii] (2006)	>3	>114	>94	Small	>43	**>254**
Webb, McKeown & Associates[xlviii] (2007)	13	82	14	-	13	**122**
SKM, CSIRO & Rural Bureau Services [xlix] (2010)	55	150	60	8	50	**323**
Basin Plan [l] (2012)	3	17.8	14	-	11.5	**46.3**
Moroka Pty Ltd[li] (2019)	3	117.8	93.5	-	21.9	**236.2**
DPIE (2019 – 2021)	49[lii]	171[liii]	99.5[liv]	50[lv]	25.2[lvi]	**394.7**

The estimates in Table 2 are long-term annual averages.

The variations in the estimates can be partly accounted for by:

- being based on different versions of the same models (Bewsher, Webb, McKeown, Basin Plan and Moroka), [lvii,lviii]
- including rainfall runoff as well as floodplain water harvesting (Bewsher and Moroka),[lix]
- excluding rainfall runoff, including only floodplain water harvesting (Basin Plan) and [lx]
- being based on an estimation of on-farm storage volumes and the hydrological impact of on-farm storages identified using satellite imaging (SKM, CSIRO and Rural Bureau Services).[lxi]

On-farm storage numbers and capacity

A critical part of licensing floodplain water harvesting is demonstrating that the licence volumes and accounting rules are within the 1994 Cap limit. DPIE has stated that the proposed licences will be within Cap but has not provided any evidence to support it.

This project has mapped on-farm storages and calculated their capacity using satellite images and Light Detection and Ranging (LiDAR). The technical description of this work is detailed in Appendix 1.

Method

On-farm storages were identified using Water Observations from Space (WOfS), a GeoScience Australia satellite imaging product. The algorithm analyses Landsat satellite imagery and detects water on the landscape. The area examined corresponded to the designated floodplains defined by the NSW Government, shown in Figure 1.

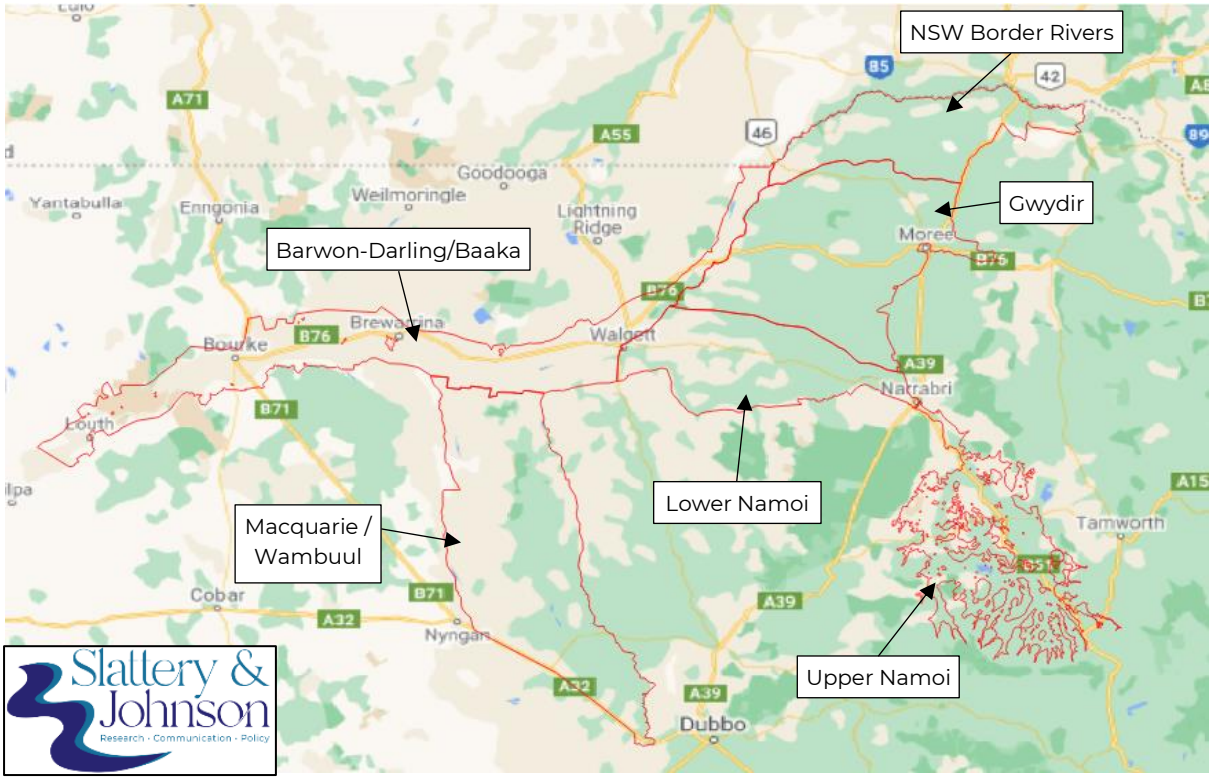

Figure 1: Field map of the study extent - northern NSW Floodplain Management Plan areas are outlined in red

WOfS detects all water on the landscape, including natural water bodies, on-farm storages and irrigated fields (for example, crops, sports ovals, parks, etc.). To ensure only on-farm storages were included in the study, other wet areas such as natural watercourses and irrigated fields were eliminated from the results. Storages less than 5,625m^2 (approximately 75 x 75m) were also removed from the results. An example of on-farm storages and irrigated fields can be seen in Figure 2.

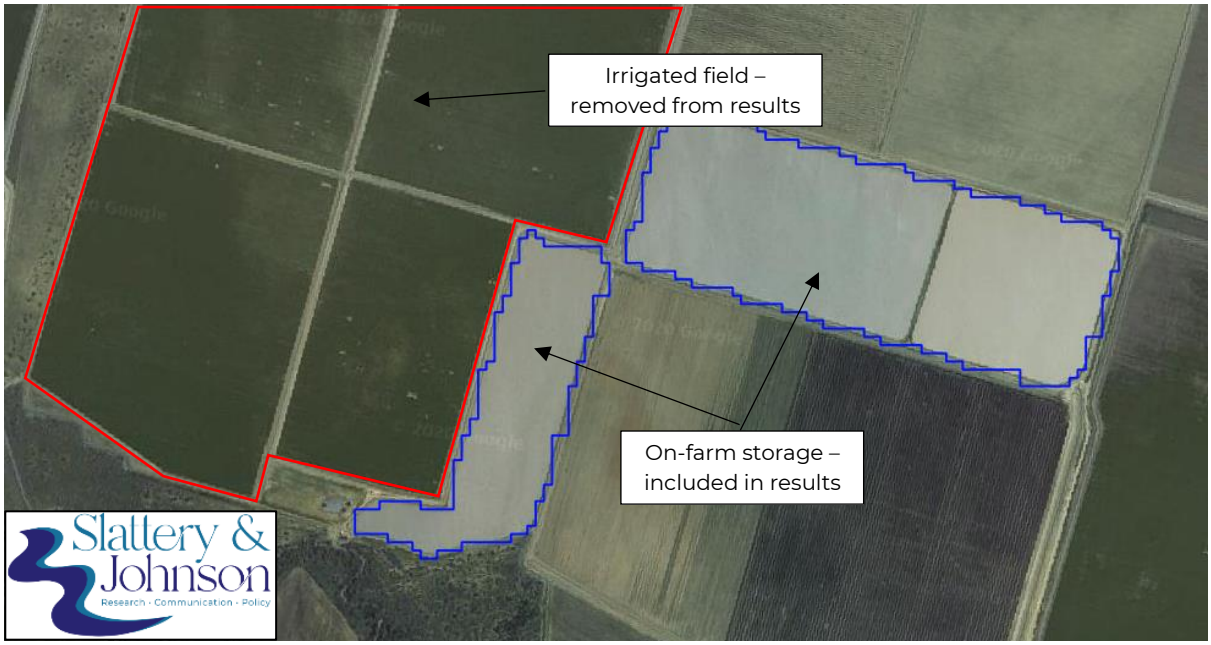

Figure 2: Distinction between on-farm storages and other water on the landscape

In the example shown in Figure 2, WOfS detects both the irrigated field and the on-farm storages as water. In this example the irrigated field would be removed from the analysis.

The analysis of satellite imagery provides the surface area of private storages. It does not provide information regarding the depth or volume of storages. The volume of the storages can be calculated based on publicly available digital elevation models (DEMs) which are derived from LiDAR data[3].

[3] DEMs downloaded from https://elevation.fsdf.org.au/ (Intergovernmental Committee on Surveying and Mapping). DEMs are derived from airborne LiDAR, a method of topographic mapping based on laser devices mounted on aircraft that determine the elevation of the ground.

Figure 3 below shows an example irrigation storage and associated digital elevation model.

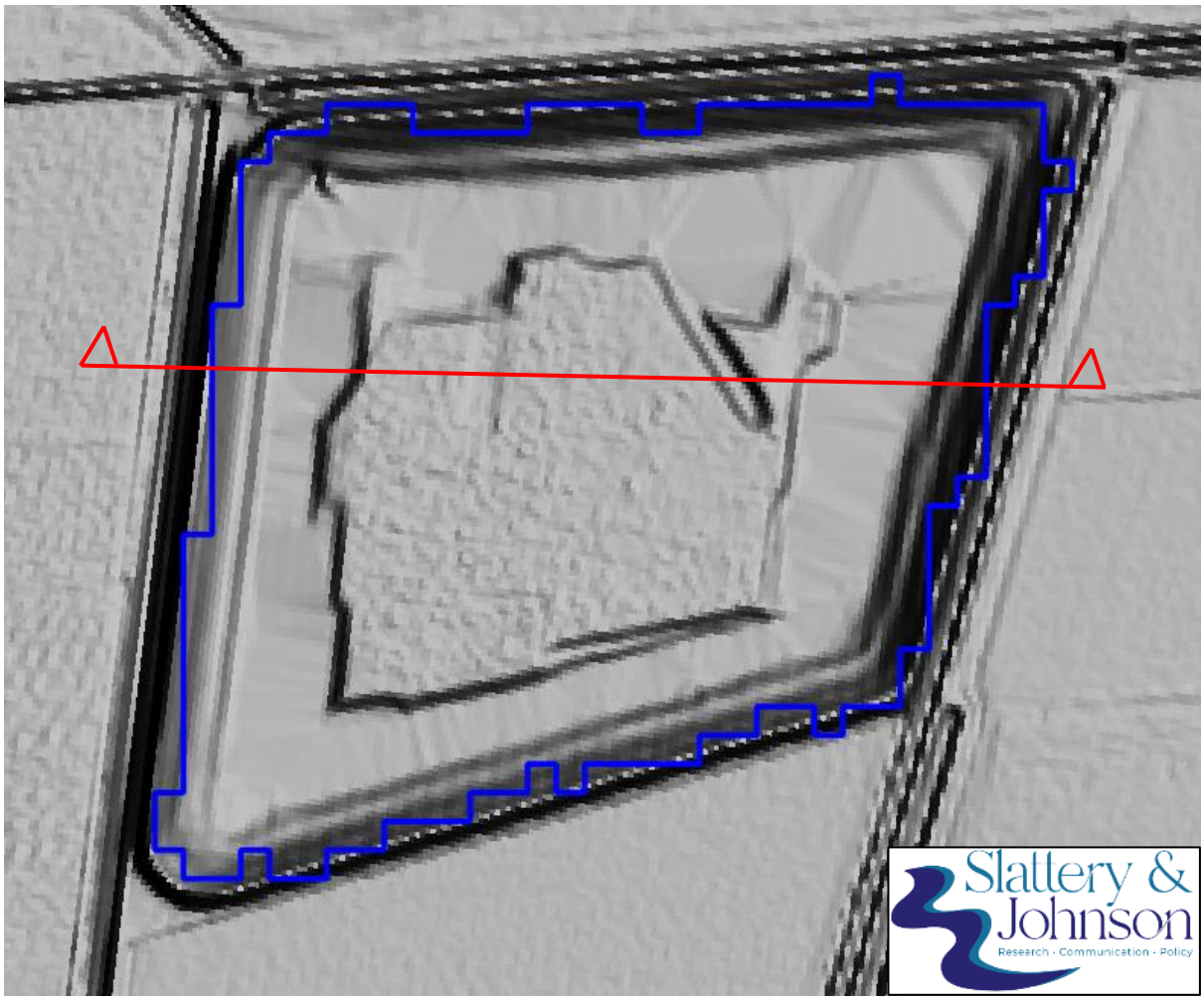

Figure 3: Example digital elevation model of an irrigation storage. Storage shown in blue and location of cross section in red.

The blue line shows the extent of the storage as detected from the satellite imagery. The grey background is the digital elevation model, effectively a 3-dimensional map of the ground. Landscape features such as banks, channels and borrow pits can clearly be identified. From the digital elevation model, a cross section (side view) can be created which shows the depth of the storage. The red line shows the location of the cross section included in Figure 4.

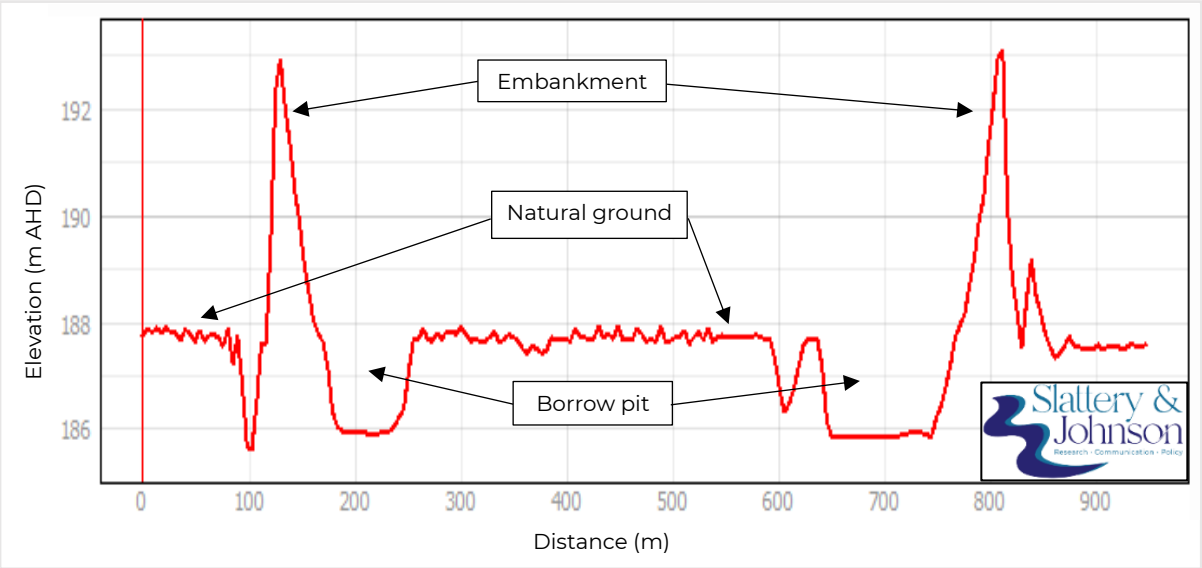

Figure 4: Example cross section (side view) of a storage.

The red line in Figure 4 represents the topography of the land. From the cross section, the storages features are readily identifiable (e.g. embankments, borrow pits) including elevation information such as the level of the top of embankments and the floor of the storage. This permits the calculation of the storage depth and volume. The example in Figure 4 shows a total depth of approximately five metres (193 metres AHD less 188 metres AHD).

Results

Figure 5 shows all the identified on-farm storages, represented as blue crosses.

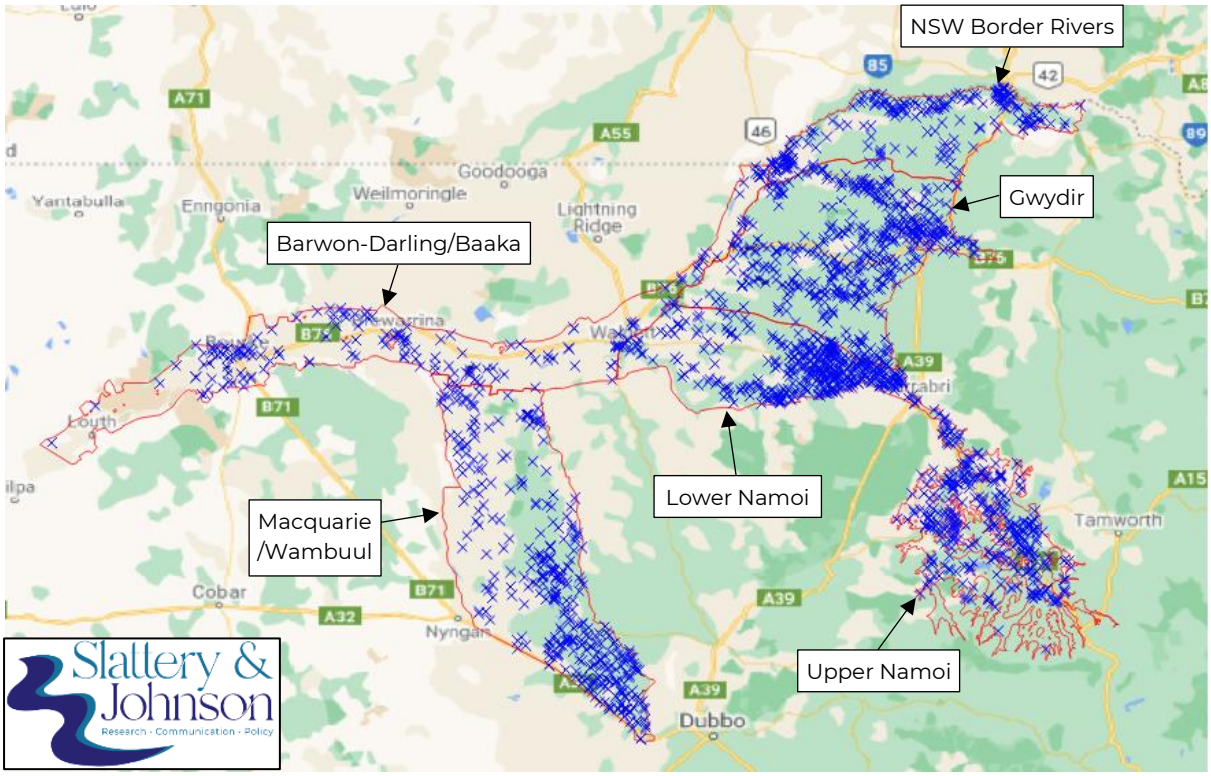

Figure 5: On-farm storages greater than 5,625m² in northern NSW. Red outlines are the Floodplain Management Plan areas

Figure 5 demonstrates the high number of on-farm storages in northern NSW, particularly in the upstream portions of the Gwydir, Lower Namoi, and Macquarie/Wambuul Floodplain Management Plan areas.

Table 3 summarises the number and total surface area of identified storages shown in Figure 5 demonstrates the high number of on-farm storages in northern NSW, particularly in the upstream portions of the Gwydir, Lower Namoi, and Macquarie/Wambuul Floodplain Management Plan areas.

Table 3: Number and surface area of on-farm storages greater than 5,625m² by valley

Valley	Number of on-farm storages greater than 5,625m²	Storage total surface area (ha)
NSW Border Rivers	191	5,800
Gwydir	434	17,200
Namoi (Upper and Lower)	695	9,200
Macquarie/Wambuul	342	5,100
Barwon-Darling/Baaka	171	5,400
Total	**1,833**	**42,700**

The total number of on-farm storages identified is 1,833. The Namoi and Gwydir valleys account for 1,129 or 60 per cent of the total number of storages. The Gwydir valley alone accounts for 40 per cent of the total storage surface area.

The volume of 252 storages was calculated based on the digital elevation models. These comprised large and small storages from all the Floodplain Management Plan areas. These storages comprised 52 per cent of the total surface area of storages, and 56 per cent of the total volume. Where the volume of a storage was not calculated from the digital elevation model, a depth was assumed based on storages of a similar size in the same Floodplain Management Plan area.

Table 4 shows the storage volumes calculated for this project compared to DPIE's calculations.

Table 4: Comparison of on-farm storage volumes

Valley	On Farm storage sizes - DPIE GL	On farm storage sizes – Slattery & Johnson GL
NSW Border Rivers	200	239
Gwydir	621	544
Namoi	219	288
Macquarie/Wambuul	172	122
Barwon-Darling/Baaka	262	203
Total	**1,474**	**1,395**

The results are similar, most likely because the method used in this project was very similar to that used by DPIE, as confirmed in correspondence from DPIE officers to the Water Minister:

> *The figures quoted by Maryanne Slattery correspond roughly with figures already provided by the Department.*
>
> *She has used the same method as the department – satellite mapping and LiDAR – to come up with a storage figure of around 1500GL currently. The Department has previously said the figure is around 1480GL.*[lxii]

A total of 1,833 water storages were detected within the study area, including 365 dams larger than one gigalitre. The total volume of all storages is 1,395 gigalitres, with dams larger than one gigalitre comprising 1,095 gigalitres or 80 per cent of total storage.

This project determined the number and volume of on-farm storages at key dates;

- 1993/94 to coincide with the Murray-Darling Basin Cap on diversions,
- 1999/2000 to coincide with NSW Plan Limits,
- 2008 to coincide with the NSW policy of issuing floodplain harvesting licences based on on-farm storages at that date, and
- 2019/20, current storage levels.

The volume of on-farm storages at those key dates is shown in Figure 6.

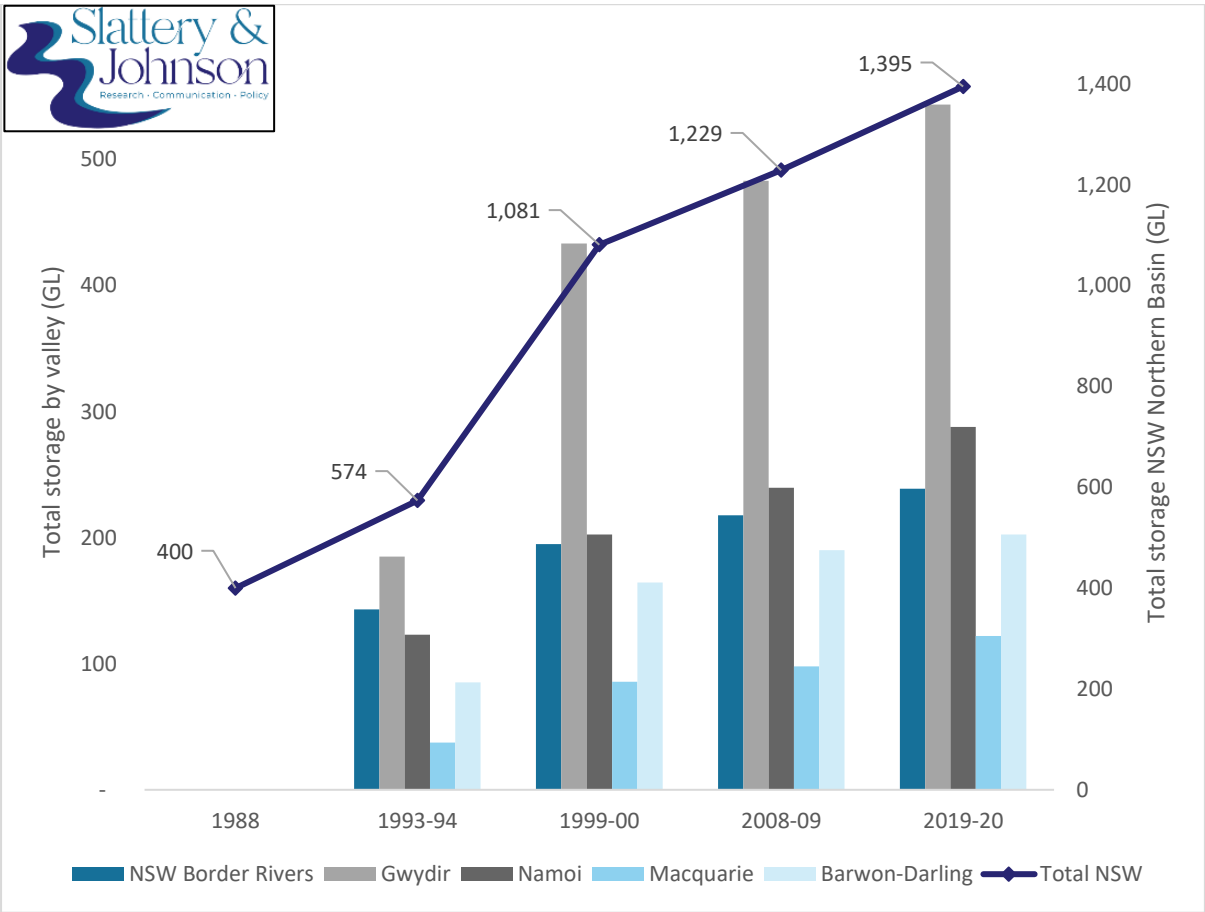

Figure 6: Estimated on-farm storages volumes from 1988 to 2020 (gigalitres)

Figure 6 shows the volume of on-farm storages by valley on the left axis, and the cumulative storage volumes on the right axis.

On-farm storage capacity has increased from approximately 574 gigalitres to 1,395 gigalitres since 1994, the Cap reference year. That is a 142 per cent increase (or 2.4 times the on-farm storage volumes at 1994).

DPIE has not provided historical storage information for the key dates. This report compares all other Government estimates since 1988, shown in Table 5.

Table 5: Estimates of On-Farm storages in the Northern Murray-Darling Basin

Valley	Murray-Darling Ministerial Council [lxiii] GL 1988	Murray-Darling Ministerial Council [lxiv] GL 1995	Webb, McKeown & Associates [lxv] GL 2007	CSIRO GL 2007 – 2008	SKM, CSIRO, Bureau of Rural Sciences [lxvi] GL 2010	NSW Department of Industry GL 2018-19
NSW Border Rivers			87[4]	77[lxvii]	169	200[lxviii]
Gwydir			351	521[lxix]	429	621[lxx]
Namoi			190	209[lxxi]	171	219[lxxii]
Macquarie/ Wambuul			110	91[lxxiii]	24	172[lxxiv]
Barwon-Darling/ Baaka			298	284[lxxv]	151	262[lxxvi]
Total	**400**	**520**	**1,036**	**1,182**	**944**	**1,474**

All estimates shown in Table 5 were either undertaken or commissioned by government agencies. A comparison between these estimates and the results of this project is shown in Figure 7.

[4] Note, the Webb, McKeown & Associates estimate was 459 gigalitres for the Qld & NSW Border Rivers and did not distinguish between Qld and NSW. CSIRO estimated the total Border Rivers at 407 gigalitres, with 77 gigalitres in the NSW Border Rivers. The 87 gigalitre estimate is based on a pro rata of the CSIRO estimate of 77 gigalitres for NSW Border Rivers out of a total 407 gigalitres total for Qld and NSW.

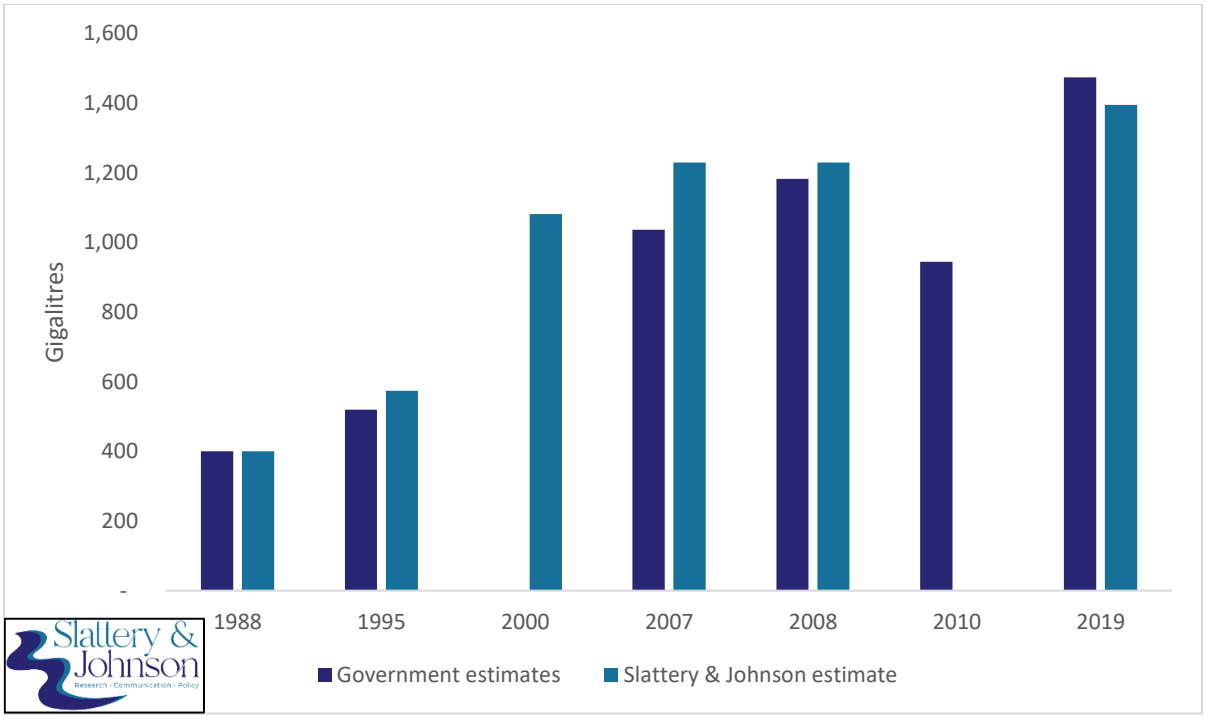

Figure 7: Historical comparison between government and Slattery & Johnson calculations for on-farm storages in the northern NSW Basin

Figure 7 shows a strong correlation for the number of on-farm storages between the government estimates over time shown in Table 5 and the figures determined in this project.

Papers made available to the NSW parliament show that DPIE confirmed to the Water Minister that the work for this report corresponds to its estimate for on-farm storage capacity in 1994 as 600 gigalitres:

> *The 1994 figure 600GL is based on satellite mapping only…The figure corresponds with the Department's estimate.*[lxxvii]

Conclusion

Water reforms in the Murray-Darling Basin are the government response to environmental degradation of river systems. Governments agreed to limit extractions to the level of irrigation development in 1994. In his address to the Press Club on 25 January 2007, Prime Minister John Howard said that;

> *...the current trajectory of water use and management in Australia is not sustainable....I announce today a $10 billion, 10 point plan on a national scale to improve water efficiency and to address the over-allocation of water in rural Australia, particularly in the Murray-Darling Basin.*[lxxviii]

However, floodplain water harvesting has never been included in Cap reporting in NSW. That is, Cap has never been complied with in respect to floodplain water harvesting.

DPIE claims that floodplain water harvesting will be limited by Cap are unsubstantiated. There has been no external verification of this claim and the documentation of the Cap models has been withheld from public scrutiny.

DPIE intends to issue floodplain water harvesting licences based on current on-farm storage capacities. It has published current on-farm storage data, but not relevant historic data.

On-farm storages are an important factor in the level of development. On-farm storages in the Northern NSW valleys has increased by 2.4 times (142 per cent) since 1994.

Appendix 1: Technical methodology

This study was undertaken using Geoscience Australia's WOfS (Water Observations from Space) algorithm to detect on-farm storages for irrigation, and to then estimate on-farm storage capacities. The WOfS product is based on the Landsat satellite which has a historical repository of images available at approximately 16-day intervals dating back to 1980. There are many remote sensing algorithms available for detecting water both in Australia and internationally and most are reasonably good at detecting water bodies[lxxix , lxxx , lxxxi , lxxxii] In this study, we used the publicly available product developed by Geoscience Australia called Water Observations from Space (WOfS). WOfS is derived from Landsat 5, 7 and 8 images and provides an analysis ready water map for the mainland Australia and Tasmania in 25 m resolution from 1986 to present. Full details of the water extraction algorithm can be found in Mueller et al. (2016). The latest version of WOfS (2.1.5) was downloaded from NCI website from the following address:

http://dapds00.nci.org.au/thredds/catalog/fk4/datacube/002/WOfS/WOfS_25_2_1/catalog.html

WOfS data is provided in GDA94 Australian Albers projection. The size of each scene is 100 × 100 km (4000 × 4000 pixels). Images were downloaded and processed using scripts written in the software program, Matlab. The scripts were prepared such that they read the rasters, applied all the masks and extracted the pixels detected to have water. The following base layers were prepared:

i. Data availability raster: this raster counted the cumulative number of days that clear data was available for each pixel during the calendar year, regardless of water being present.
ii. Water availability raster: this raster counted the cumulative number of days that water had been detected in each pixel during the calendar year.
iii. Water availability proportion raster: this raster was produced by dividing water availability with data availability rasters explained in steps i and ii and shows the percentage of times water was detected for the clear and cloud free images.

A raster consists of a matrix of cells (or pixels) organized into rows and columns (e.g. a grid) where each cell contains a value representing information, such as colour. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.

Water availability proportion rasters were compared to aerial images to find a threshold to detect waterbodies. This was done because WOfS classified highly irrigated terrestrial areas such as football fields as water, this type of error is known as commission error. We eliminated a large number of these commission errors by applying a threshold of >30 per cent of water availability percentage for

each water year (1993/1994, 1999/2000, 2008/2009, and 2018/2019) on the water availability proportion maps.

GIS analysis

Raster maps were converted to vector format and water body polygons were created, producing 5 shapefiles (one for each modelling year and an additional representing the total). A unique ID number was assigned to each unique water body found in each year. We dissolved each shapefile and an artificial water storage layer published by Geoscience Australia into a single shapefile to find the maximum extent of each water body and in doing so harmonised the waterbody id between WOfS water years.

Natural waterbodies such as rivers, lakes, wetlands, and swamps were prevalent and were filtered from the artificial water storages. We removed the natural waterbodies by clipping out the natural areas that intersected with the Australian National Aquatic Ecosystem geodatabase layer (lacustrine, palustrine, and riverine wetland layers). In some instances, the ANAE layers were incomplete or did not cover the full extent of the natural waterbody. In these instances, we manually digitised the area with high resolution imagery, so that any masking could be consistently applied across time. In addition, we removed wetland, swamps, and tributaries by imposing an additional buffer of 100 metre on each side of the riverine shapefile. In instances, where water storages were within the 100 metre buffer, the buffer was manually edited to incorporate the water storage, this was done visually.

Water bodies that were not irrigation storages (e.g. wetlands, rivers, irrigated fields, sports fields) were removed. This process was partly automated using publicly available shapefiles of natural water bodies and by manual inspection of the satellite images, as shown in Figure A1.1. Where we applied manual validation we used high resolution imagery to select and eliminate the non-irrigation storages. Similarly, dark objects (e.g. black soils), building shadows and steep slopes were other observed commission errors. These errors were manually digitised and eliminated.

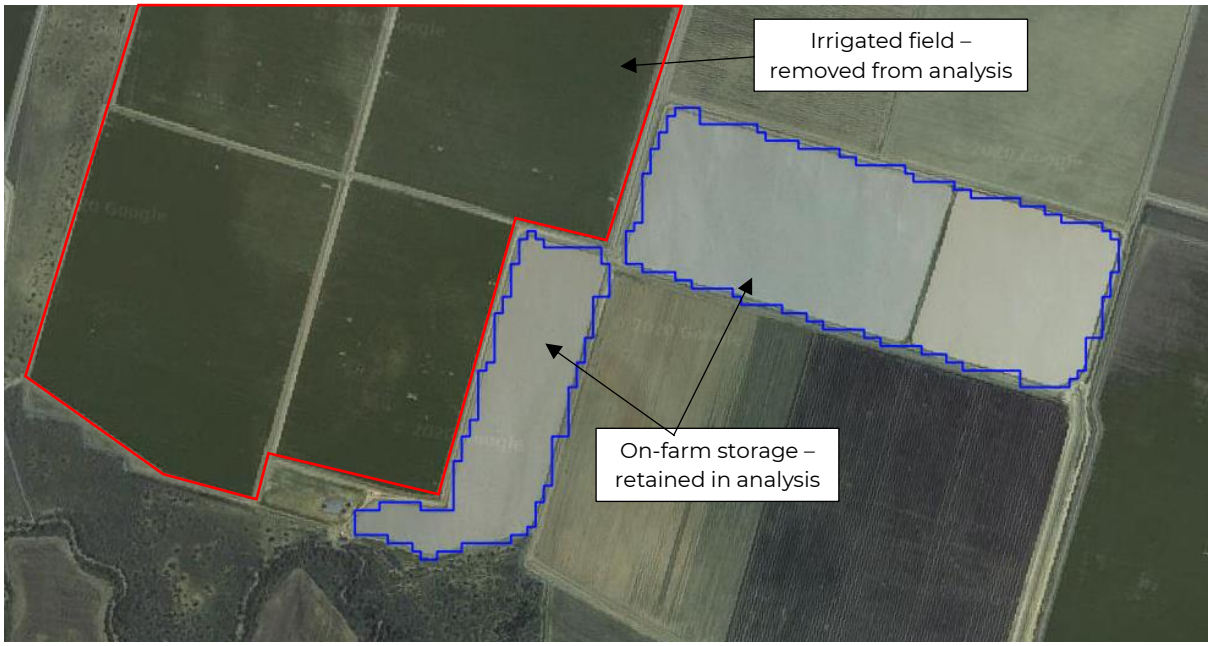

Figure A1.1. Manual inspection to remove non irrigation waterbodies

The images in Figure A1.1 are an example of manually identifying a water body with a large channel as an on-farm storage (top left arrow), rather than a wet paddock (top right arrow), that might otherwise be mistakenly interpreted as a storage.

Calculating volume

The analysis of satellite imagery provides the surface area of water detected during the study period. It does not provide information regarding the depth of dams. Depth information is obtained from analysis of publicly available digital terrain models (DEMs), which are derived from LiDAR data. The Elvis online portal provides access to publicly available DEMs throughout Australia[5].

The DEMs can then be interrogated using the software package QGIS to determine the volume of the storages, using the 'Raster Surface Volume' tool. The volume of 252 storages was calculated using this method. These storages comprised small, medium and large size storages across all the different floodplain management plans. These storages comprised 52% of the total surface area of storages, and 56% of the total volume. Where the volume of a storage was not calculated from the DEM, a depth was assumed based on storages of a similar size in the same Floodplain Management Plan area.

[5] Intergovernmental Committee on Surveying and Mapping, https://elevation.fsdf.org.au

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