SUSTAINABLE **IRRIGATION** MANAGEMENT UPDATE

Management of irrigation water storages: carryover rights and capacity sharing

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5. MORE INFORMATION

ABARE research reports:

Capacity sharing in the St George and Macintyre Brook irrigation schemes in southern Queensland (2009) Hughes, N. and Goesch, T.

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6. REFERENCES

Dudley, N. and Musgrave, W. (1988) "Capacity sharing of Water Reservoirs', *Water Resources Research*, Vol 24, pp. 649-658.

SunWater Pers. Comm. (2008) Manager of Corporate Strategy, Tom Vanderbyl. 21/01/08.

Freebairn, J. and Quiggin, J. (2006) Water rights for variable supplies, *Australian Journal of Agricultural and Resource Economics* 50, pp. 295-312.

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1. SUMMARY

Water storages (reservoirs) play a vital role in the supply of water for irrigation farms, serving to smooth variation in supply and maximise the economic value of water over time. Their appropriate management is particularly important in Australia, given the extreme variability of inflows and predictions of lower and more variable inflows in the Murray Darling Basin due to climate change.

In Australia, major irrigation water storages are centrally managed via an announced allocation system, where each season a water manager determines the amount of water available for use now given prevailing storage levels. However, a centralised allocation approach used on its own may fail to achieve an ideal allocation of water across irrigators and time. In particular because the water/storage manager is unlikely to have complete information on the water preferences of irrigators.

An economic model of the storage problem facing a representative irrigation system was developed to demonstrate the potential benefits of improved management. The model demonstrated that ability of optimal storage management to lead to gains in average irrigator incomes and reductions in the variability of incomes. The model also showed that the benefits from optimal storage management increased substantially as the level of water availability reduced.

Given the practical difficulties of a centralised approach, a decentralised approach, where irrigators can make their own storage decisions, may be preferable. This project looked at two decentralised approaches: carryover rights and capacity sharing.

Carryover rights allow each water user to hold over a proportion of their seasonal water allocation for use in the future. While of some benefit, carryover rights are subject to significant practical limitations. In particular individual carryover decisions can impose adverse external affects on other irrigators in a system. In an attempt to minimise these external effects, significant restrictions are often placed on carryover rights, further weakening their effectiveness.

With capacity sharing, users are allocated a share of system storage capacity and inflows. They manage these shares independently, determining how much water to use and how much to store for the future. Capacity sharing results in water rights that more closely reflect the physical realities of the water supply system. Unlike carryover rights, it minimises external effects and ensures users are responsible for their contribution to storage losses. Capacity sharing replaces the traditional announced allocation system, removing a layer of regulatory uncertainty from existing water entitlements.

Capacity sharing has been used in the St George region in southern Queensland since 2000, and the nearby Macintyre Brook region since 1 July 2008. These are the only irrigation regions in Australia to implement the system at the end user level.

ABARE conducted informal interviews with irrigators and members of the finance sector in the two regions. All irrigators supported capacity sharing, citing a number of advantages, such as greater flexibility and a reduction in uncertainty. The financiers were generally supportive, regarding it as a more transparent system with less uncertainty.

Adoption rates show the take-up of capacity sharing has been strong. As of the 2008-09 water year, over 99 per cent of entitlements by volume were under capacity sharing at St George and over 98 per cent at Macintyre Brook in its first year in operation.

The St George water accounts show significant end-of-year storage reserves, despite the relatively low inflows during the period and the relatively high storage losses. The user level data presented in the report demonstrates that even in relatively small systems, with limited crop diversity, individual irrigators display highly variable water use/storage preferences. One of the advantages of capacity sharing is that it permits irrigators to adopt diverse water use/storage strategies, without affecting other irrigators in the same system.

The experience of St George and, to a lesser extent, Macintyre Brook, demonstrates that capacity sharing is feasible, practical and even successful. While there are challenges to face in refining the approach and introducing it into other systems, capacity sharing shows significant potential and deserves further attention from water policymakers.

2. BACKGROUND

The management of irrigation water storages involves repeated comparison of the benefits of consuming water today against the expected benefits of storing water for future use. Determining what proportion of water to store is complex, given the substantial uncertainty over future inflows and demands.

Storage policies involve a yield-reliability trade-off. For example, policies may be described as conservative (low yield-high reliability) or aggressive (high yield-low reliability). Here yield refers to the mean water release/use level, while reliability to the variability of releases. A conservative rule would, on average, release a smaller percentage of available water for immediate use, holding more over in storage for the future, resulting in higher reliability.

In Australia, state governments have traditionally centrally managed the major water storages, making decisions on current allocations given prevailing storage levels and expectations of future conditions. In practice, a number of factors could prevent a centralised storage management policy from achieving optimal allocation. Where a central manager adopts a sub-optimal storage management policy, this may lead to reduced irrigator incomes and increased income variability.

An alternative to central control of water storages is a decentralised approach. Carryover rights allow water users to hold over a proportion of their seasonal allocation for use in the future. These rights have been widely adopted within the Murray-Darling Basin but, for a number of reasons, are a less than ideal solution to the storage problem.

Capacity sharing is an alternative system of property rights first proposed by Dudley (Dudley and Musgrave 1988). Rather than allocating users a share of total releases, each user is allocated a share of total storage capacity, as well as a share of inflows into, and losses from, the storage. Capacity sharing has been adopted successfully by SunWater at St George in south-west Queensland and more recently in the nearby Macintyre Brook region. Capacity sharing has a number of potential advantages over traditional water property rights systems, however it is largely untried outside Queensland.

SunWater commonly refers to its capacity sharing arrangement as 'continuous sharing', a term not to be confused with continuous accounting carryover. SunWater uses this term to reflect the fact that its approach involves some extensions to the original capacity sharing concept. In order to avoid confusion, the 'continuous sharing' schemes in Queensland will be referred to as capacity sharing in the rest of this report.

3. APPROACH

Theoretical analysis

The first task of this project was to provide a theoretical analysis of water storage management. This involved the development of a theoretical model of the storage problem facing a representative irrigation system.

The model incorporates representations of the demand for water by irrigators and the irrigation water supply system (e.g. inflows, storage and associated losses). It is stochastic, in that inflows into storages and rainfall are subject to random variation, and is an optimisation model in which a social planner (e.g. water utility) determines the appropriate allocation/release level each period to maximise returns to irrigators in the long run.

This model provided a framework to analyse the merits of centralised storage management, in particular the conditions under which a centralised approach could result in an ideal allocation of water resources were outlined. The analysis then identified reasons why these conditions might be broken.

Quantitative water storage model

The model was applied to a case study region to demonstrate potential benefits of improvements in storage policy (or costs of inadequate policy). A computer-based version was developed and parameter values included price elasticity (price responsiveness), irrigation water demand and probability distributions over inflows and rainfall.

The case study was based on the Murrumbidgee region in NSW. Model parameter values were set with reference to historical data and estimates from statistical literature.

Assessing capacity sharing in Queensland

Assessing the capacity sharing schemes in Queensland involved gathering qualitative information through interviews and the analysis of quantitative data. Informal interviews were conducted with irrigators and members of the finance sector in both regions. ABARE interviewed four irrigators at St George (two cotton growers, a table grape grower and a fruit and vegetable grower) and two at Macintyre Brook (a broadacre cropping and livestock farmer and an organic chicken farmer). Four members of the rural finance sector were interviewed by phone.

SunWater supplied qualitative data, including capacity sharing adoption rates, historical hydrological data and data from its accounting system. This was analysed to gather insights about how the capacity sharing schemes operated in the two regions. For example, user level data from the accounting system was used to construct a set of aggregate water accounts, showing monthly aggregate water inflows, withdrawals, storage losses and reconciliation volumes.

4. KEY FINDINGS AND MANAGEMENT IMPLICATIONS

Centralised storage management

In Australia, storage management decisions occur via an announced allocation system, where each season the dam manager (generally a state government body or a state government-owned entity) announces a percentage allocation: the percentage of nominal water entitlement volume available for use (or trade) by the entitlement holder that season.

For a centralised storage management policy to achieve an efficient allocation of water across time and irrigators, the dam manager requires complete information on the water needs of irrigators, and trade in water allocations must be efficient and costless. Under these conditions the optimal amount of water would be released and the water efficiently allocated across individual irrigators via trade in allocations.

In practice, these conditions may not be met, leading to inefficient allocation. In particular, there may be asymmetric information between the storage manager and irrigators and transaction costs in water trade.

Asymmetric Information

Asymmetric information means that irrigators are likely to have information on their water demands that will not be available to dam managers. It is unlikely that managers will obtain full information on aggregate water preferences without knowing all of the preferences of individual irrigators. Obtaining information on preferences can be difficult because they are likely to vary significantly between irrigators, and preferences are likely to change over time. With asymmetric information, a central manager may implement a sub-optimal allocation policy, lowering average returns to irrigators in the long run.

Transaction costs in water trade

Transaction costs are incurred when making an economic exchange. Evidence suggests irrigators face significant transaction costs when trading water allocations in the Murray-Darling Basin, including government and brokers' fees, as well as non-financial indirect costs, such as time costs incurred.

Under a simple announced allocation system, substantial temporary trade in water allocations may be required to achieve an efficient allocation. Any system of water property rights which better aligns entitlement reliability levels with individual irrigator reliability preferences will reduce the need for temporary water trade and an irrigator's exposure to associated transaction costs.

High and low reliability entitlements

High and low reliability entitlement systems (referred to as general and high security entitlements in NSW) are common in the Murray-Darling Basin. They have the potential to reduce temporary water trade requirements (and reduce an irrigator's exposure to transaction costs) by providing water rights that more closely match the reliability preferences of individual irrigators (Freebairn and Quiggin 2006). However, systems of high and low reliability entitlements do have a number of practical limitations.

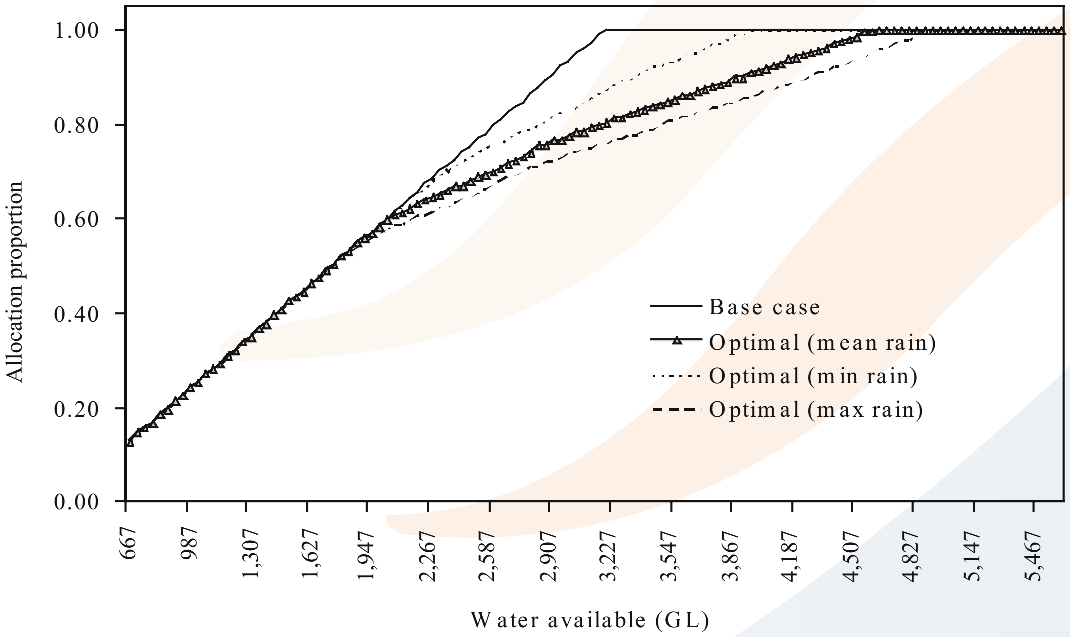
Implications for Investment

While not considered in detail in this report, it is likely that storage management polices will have important implications for irrigator investment decisions. The policies, by influencing the yield-reliability levels of water entitlements, will influence the relative attractiveness of different irrigated activities. In the long run, a fixed centralised storage policy may act as a constraint on irrigator investment, preventing an optimal distribution of low and high flexibility irrigation activities.

Model Results

Using the developed quantitative economic model, an arbitrary 'aggressive' release (allocation) rule was compared with a theoretically optimal release rule. Figure 1 below compares the base case 'aggressive' release policy (release all water up to 100 per cent of entitlements) with the estimated optimal release policy. The estimated optimal release policy involves holding more water in storage reserves relative to the aggressive policy.

Figure 1: Estimated optimal release rule



The estimated optimal release rule involves a small reduction in mean water use for a substantial increase in mean storage reserves, minimising variation in the supply of, and value of, water over time. It typically results in less water being available in wet years and more being available in drought conditions. The model demonstrates the ability of optimal storage policy to lead to an increase in mean irrigator incomes and a substantial reduction in variability of incomes. The model estimated an increase in mean surplus to irrigators of 11.8 per cent and a reduction in the variability of surplus of more than 63 per cent (Table 1).

Table 1: Simulation results, deviation from base

	UNITS	MEAN	S.D	C.V.
Allocation	%	-0.6	-27.2	-26.7
Price	%	-16.3	-55.6	-47.0
Storage level	%	134.8	14.7	-51.2
Evaporation Loss	%	11.8	1.6	-9.2
Water Demand/Use				
Irrigator 1	%	-0.8	-27.1	-26.5
Irrigator 2	%	0.2	-28.6	-28.7
Objective Value	%	11.8	-58.9	-63.3

A sensitivity analysis demonstrated that the gains from optimal storage management (both in terms of mean and variability of incomes) increase substantially as the level of water availability reduces (Table 2). These results confirm that with greater water scarcity there is more to be gained by improving the management of irrigation water storages, i.e. when inflows are lower and less reliable there is more to be gained by holding water in storage to insure against drought. This is an important result given predictions of reduced water availability across much of the Murray-Darling Basin due to climate change.

Table 2: Sensitivity analysis, reduction in inflow/rainfall

	UNITS	SCENARIO			
Rainfall Mean	% change	0	-5	-10	-15
	(mm)	406.6	386.3	365.9	345.6
Inflow Mean	% change	0	-15	-30	-45
	(GL)	2,704	2,301	1,898	1,491
Base Case					
Mean Price	$/ML	65.7	115.3	243.0	555.4
Mean Objective	$ Million	354	315	273	206
Optimal Policy					
Mean Price	$/ML	55.1	69.3	89.1	128.1
Mean Objective	$ Million	395	382	362	332
Deviation					
Mean Price	% change	-16.3%	-39.9%	-63.3%	-76.9%
Mean Objective	% change	11.8%	21.2%	32.6%	61.8%

Carryover rights and capacity sharing

An alternative to centralised storage management is a decentralised approach, giving individual irrigators greater control over decisions. In the report two decentralised approaches are considered: carryover rights and capacity sharing

Carryover rights

Carryover rights allow water users to hold over a proportion of their seasonal water allocation for use in the future. They have been used in NSW and Queensland irrigation systems for some time and have recently been introduced into a number of Victorian and South Australian systems.

While carryover rights may help irrigators overcome some of the problems associated with central storage management, they are an incomplete solution because they do not explicitly define rights to storage capacity or to associated storage losses. As such, individual carryover decisions affect other users of the same storage. Carryover provisions are often limited by restrictions imposed on their use that, while designed to minimise external effects, may prevent irrigators from making the best storage decisions. Access to carryover water may also be subject to sovereign risk, demonstrated recently where irrigators were denied access to carryover water during drought.

Continuous accounting is a form of carryover where user's accounts are updated on a more frequent (generally daily) time scale. However, this still involves centralised allocation announcements and does not redefine water rights at the source.

Capacity sharing

Capacity sharing allocates property rights to water from shared storages (Dudley and Musgrave 1988). Each entitlement holder in an irrigation system is assigned a share of total storage capacity as well as a share of total inflows. Users manage these shares independently, determining how much water to use (or sell) and how much to leave in their share of storage. Capacity sharing results in water entitlements that more closely reflect the physical realities of the water supply system: constrained storage capacity, variable water inflows and significant storage and delivery losses.

Unlike carryover rights, capacity sharing ensures that storage space is efficiently rationed and that losses are internalised, and may also reduce regulatory uncertainty. Under a standard announced allocation system, irrigators are exposed to regulatory or government uncertainty, since allocations depend not only on water availability, but the policies of storage managers. Under a capacity sharing system, the yield and reliability of any given water entitlement depends only on an irrigator's water use/storage decisions and the hydrology of the supply system.

Capacity sharing involves redefining water rights at the source, which can improve efficiency, and because no central allocation decisions are required, the potential for insider trading is reduced.

One complication, however, is the occurrence of internal spills: where individual water accounts reach capacity and forfeit their inflows to other water users. However, the economic cost of this is negligible and such spills are likely to occur infrequently. While adopting capacity sharing is likely to involve substantial set-up costs, once in place operating costs are likely to be relatively low, potentially lower than announced allocation systems. Another important consideration would be to minimise any actual or perceived distributional impacts, by ensuring the newly defined capacity share water entitlements adequately preserved all existing irrigator water entitlements.

Capacity sharing is typically considered for relatively simple supply systems (where all water is sourced from a single storage), its broader application is a subject for potential future research.

Capacity sharing in southern Queensland

Capacity sharing has been used in the St George region in southern Queensland since 2000, and was introduced into the nearby Macintyre Brook region on 1 July 2008. These are the only irrigation regions in Australia where the schemes have been implemented at the end user level.

Assessing capacity sharing in southern Queensland

Interviews

SunWater's perspective

From SunWater's perspective capacity sharing has been a highly successful policy in the St George region, reducing operating costs and disputes with irrigators.

Irrigator interviews

All irrigators interviewed supported capacity sharing. Those in St George said benefits included internalisation of storage losses, leading to a reduction in external impacts, increased flexibility in seasonal timing of water use and reduced uncertainty. They also suggested capacity sharing facilitated diversity between water users with different crop types, risk preferences and water use strategies.

Irrigators at Macintyre Brook noted that, in the past, carryover rights were limited in their region and capacity sharing provided much more control over storage decisions and water supply reliability. They also found it reduced uncertainty and stressed the benefits of the internalisation of delivery losses.

The irrigators indicated the transition to capacity sharing was well handled, with no significant opposition from irrigators in either region. They also indicated that it did not impose any significant time or inconvenience costs and that it was easy and low cost to use.

Finance sector interviews

Three of the financiers supported capacity sharing, indicating it was a more transparent system subject to less uncertainty. One said that this increased certainty provided lenders with more confidence in extending financial support to irrigation farms, at least in the short term. One financier was concerned at the delivery loss zones in the Macintyre Brook system, suggesting some irrigators who regularly traded water to downstream regions were adversely affected. Macintyre Brook irrigators expressed similar concerns.

Addressing some concerns

SunWater's entitlement conversion rules ensure that capacity share entitlements provide equivalent volumes of water 'on farm' as existing water entitlements. However, they do not necessarily ensure that the relative market values of water entitlements in different loss zones remain constant. Irrigators who regularly trade large proportions of their water allocations downstream may potentially be affected by changes in relative market prices. However, it is unclear whether this has led to any significant net distributional affects on irrigators at Macintyre Brook.

In the capacity sharing schemes implemented by SunWater, rights to storage space and inflows are bundled together and cannot be traded separately. In theory, trade in bundled capacity share combined with trade in physical water should provide an adequate substitute for separate storage rights. In practice, water markets are likely to involve significant transaction costs; as such, separate inflow and storage rights may be desirable to reduce an irrigator's reliance on temporary water trade and associated transaction costs.

Quantitative data

Hydrological data

Historical inflow data for the St George region demonstrates a relatively high level of variability (both at an annual and monthly time scale). St George, as with many Queensland systems, is subject to extreme high inflow events of significantly greater size and frequency than observed further south in the MDB. Historically, average inflows at St George have substantiality exceeded the region's maximum storage capacity. However, since 1999-2000 inflows have been well below this average. Capacity sharing (introduced in 2000) has therefore been operating during a period of unprecedented water scarcity.

Adoption rates

In both schemes SunWater maintains an announced allocation system alongside its capacity sharing systems and the adoption of capacity sharing by irrigators is voluntary. Adoption rates show the take-up has been very strong. As of the 2008-09 water year, over 99 per cent of entitlements by volume were under capacity sharing at St George and over 98 per cent at Macintyre Brook in its first year in operation.

Table 3: St George volume of water entitlements under capacity sharing

WATER YEAR	CAPACITY SHARING	BULK SHARING
2002-03	82,840	1,644
2003-04	83,908	576
2004-05	83,938	546
2005-06	83,958	526
2006-07	83,939	545
2007-08	84,032	452
2008-09	84,077	407

Table 4: Macintyre Brook volume of water entitlements under capacity sharing

WATER YEAR	CAPACITY SHARING	BULK SHARING
2008-09	24,519	478

Aggregate water accounting data

The St George water accounts show significant end-of-year storage reserves, despite the relatively low inflows during the period and the relatively high storage losses. The water accounts also show how annual storage reserves serve to minimise variation in water use between years, and within years.

Table 5: Aggregate annual water account, all irrigators, St George (2004-05 to 2007-08)

	UNIT	2004-05	2005-06	2006-07	2007-08
Opening storage volume	ML	54,167	32,837	31,529	5,431
Inflows					
Inflows	ML	66,944	101,021	12,895	92,828
Overflows[a]	ML	3,969	9,485	0	18,454
Total Inflows	ML	70,913	110,506	12,895	111,282
Outflows					
Storage losses	ML	36,421	40,817	12,759	36,152
Reconciliation	ML	+11,117	+5,801	+5,918	+6,655
Withdrawals[b]	ML	67,983	76,427	33,144	49,998
Total Net Outflows	ML	93,287	111,443	39,985	79,495
Est. ending storage volume	ML	31,792	31,900	4,439	37,217
Act. ending storage volume	ML	32,837	31,529	5,431	36,027
Ending storage percentage	%	42	40	7	46

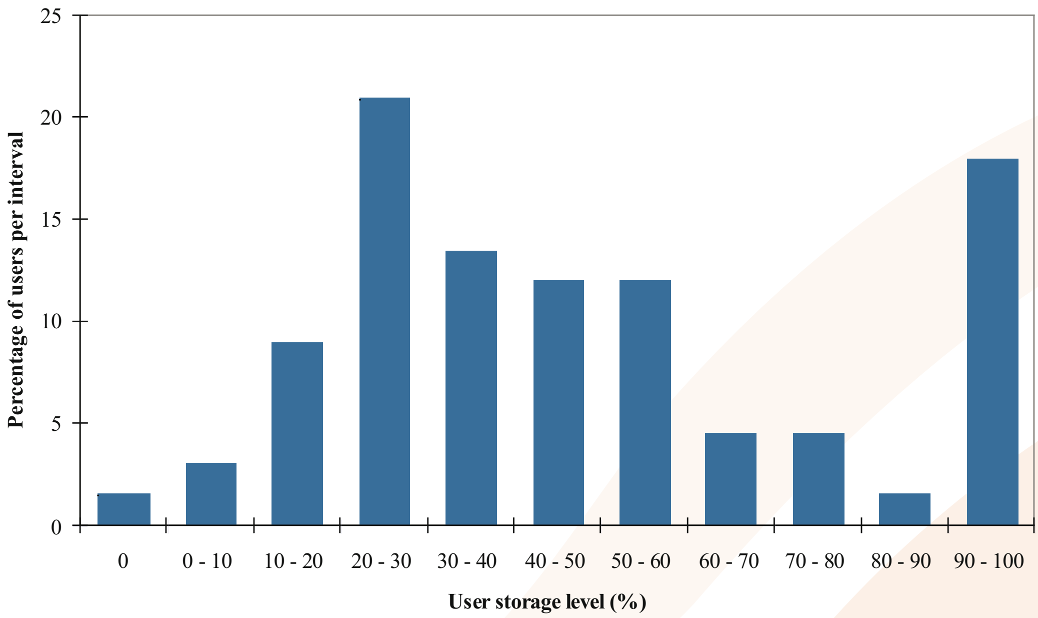
a Water credited to irrigators (debited from environmental water account) in the event of storage spill.
b Including water delivery losses.

Note: Estimated ending storage volumes are calculated as the balance of all water year transactions (opening storage volume plus inflows and overflows less storage losses and withdrawals plus reconciliations). Actual ending storage volumes are those reported in end of year remaining balance data.

User level accounting data

User level water accounting data from the two capacity sharing schemes is also presented in the report. This shows the extent of variation in water use/storage strategies across individual irrigators.

Figure 2: Individual user storage volume (percentage full) at St George (End of 2004-05 water year)



The user level data shows that even in relatively small systems, with limited diversity in agricultural activity, individual irrigators display highly variable water use/storage preferences. One of the advantages of capacity sharing is that it permits irrigators to adopt diverse water use/storage strategies, without affecting other irrigators in the same system.

A longer, seven-year time series of user level water withdrawal data was available for the St George capacity sharing system. This data shows significant variation in irrigator water use/storage practices, both across years and within years. Significant variation was observed in the mean yield (mean water use relative to storage capacity) and variability levels of individual water accounts, and in the timing of water use within the water year across different irrigators. Larger water users (e.g. cotton growers) used more water in the December peak period while smaller users (e.g. grape growers) used water more consistently across the year.

User level inflow data was used to estimate internal spill volumes for St George. The data shows that internal spills are relatively infrequent. However, there were a small number of particularly large spills, exclusively associated with extreme high inflow events, where the main dam filled in a few days. It is likely that in other systems, with greater storage capacity and less variable inflows than St George (such as those further south in the MDB), internal spill volumes would be significantly lower on average.