ESTIMATING STOCK AND DOMESTIC WATER USE TO IMPROVE CATCHMENT WATER MANAGEMENT OUTCOMES

Method, results and contribution of different tools to improving catchment management outcomes in the Port Phillip and Westernport Basin in Victoria

C Larsen, M Toulmin, D Wallis, B Moulden, S Gaskill, A Lucas

INTRODUCTION

BACKGROUND

A holistic management approach to water resource planning is required to ensure sustainable and equitable allocation between consumptive and environmental water needs (DSE, 2008). Section 8 of the *Water Act 1989* (Vic) provides landholders with private rights to access water in dams, groundwater and waterways for domestic and stock (D&S) purposes. The levels of D&S use are not well documented, as the private right is not registered, licensed or metered. This use includes water for:

- Household purposes
- Watering cattle or other stock and animals kept as pets
- Watering a kitchen garden for household use
- Watering an area around the house (known as the curtilage) for fire prevention purposes (applicable to water sourced from a dam only).

Historically, usage has been coarsely estimated by reference to the sources of supply, i.e. an assumed volume per dam, groundwater bore or river frontage. This has generated a relatively high presumed level of consumption. Increased concern for whole of catchment accounting has triggered a desire to better understand the quantum and source of D&S water use at a catchment and basin scale to allow an assessment of materiality and to target future programs.

This paper discusses the method developed and the results of a project for estimating D&S water use and the contribution of different tools to improving catchment water management outcomes in the Port Phillip and Westernport Basin, Victoria.

PROBLEM DEFINITION

Environmental flows are a key component of waterway health, in conjunction with other key environmental conditions of waterways including water quality, physical form, habitat and connectivity (Melbourne Water, 2012). Melbourne Water facilitates the development of *Stream Flow Management Plans* (SFMPs) in the major sub-catchments of the Yarra River and is the waterway manager for the entire Port Phillip and Westernport Basin. *Stream Flow Management Plans* are developed by SFMP Consultative Committees and outline how surface water resources are shared among licensed users and the environment. This approach will become increasingly important in the context of future water availability and projected impacts on run-off and stream flow (DSE 2008).

Several SFMP Consultative Committees, comprised largely of licensed diverters, have expressed concern about the level of unlicensed water use within their catchments. The National Water Commission has also identified the construction of licensed and unlicensed farm dams as a significant water intercepting activity that warrants further research (NWC, 2010).

Over the past few decades there has been a significant expansion in the number of rural lifestyle properties in many parts of the Melbourne Water region, particularly on the rural-urban fringe. Many of these developments do not provide a reticulated supply of water and rely on landowners to develop their own domestic water supply. Dams provide a cheap and potentially reliable source of domestic water for such properties, as well as a strategic reserve for fire-fighting purposes. Dry conditions in the last decade have also increased the demands for reliable water supplies for properties on the urban fringe, resulting in very high and increasing density of small dams in some areas.

Other studies using hydrological simulations have indicated that farm dams can reduce stream flow by more than 10%, even in catchments where most dams are small and unlicensed (SKM, 2011).

A greater understanding of D&S water use is required to address the potential impacts on stream flow and to respond to community concern. To effectively manage D&S water use, Melbourne Water needs to know the demand characteristics and volume and sources of supply. Having an improved estimate of the total amount of water being used allows the importance of D&S water use in relation to licensed use to be assessed. Knowing the sources of D&S water use will assist in determining how to address impacts on stream flow.

METHODOLOGY

OVERVIEW

RMCG developed an alternative approach to estimating probable levels of D&S consumption. This is based on an estimate of demand calculated from reliable sources of data, which is then compared with evidence on sources of supply. A three-tiered methodology has been developed for estimating D&S water use, where the three approaches allow cross-referencing and triangulation of results to provide for internal cross-checking (RMCG, 2011). The schematic representation of the methodology is shown in Figure 1.

HIGH-LEVEL MODEL

The first component of the methodology is a high-level model that sources readily available information related to the catchment (ABS, 2010; Ceena, 1983; DPI, 2010; DSE, 2002; DSE, 2010a; DSE, 2010b; DGC and SKM, 2009; Lowe *et al.*, 2009; SKM, 2005; SKM, 2009a; SKM, 2009b;

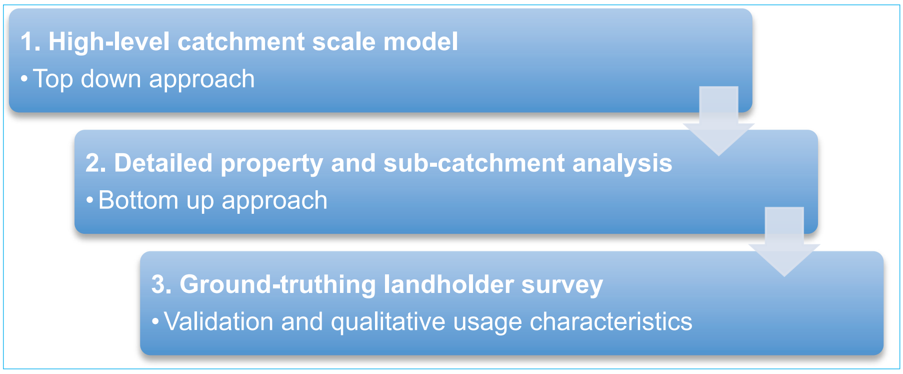

Figure 1. Schematic representation of D&S assessment methodology.

The Public Land Consultancy, 2008). A spreadsheet model analyses and converts this information to produce catchment scale data on total demand and likely supply sources. The model provides resource managers with an understanding of the current and possible D&S use between an upper and a lower limit of probable demand:

- Upper limit of demand: This provides a maximum development scenario, for future potential demand within the catchment if all properties were to exercise their full D&S right and graze to maximum carrying capacity. The upper figure for demand is often far in excess of the potential capacity of the available sources of D&S supply;
- Likely current demand (lower limit): This represents a projection of probable levels of demand given assumptions about the level of activity and types of demand. This takes account of the proportion of life-style properties and so the level of grazing that is likely to occur.

A schematic representation of the high-level D&S model is shown in Figure 2. This flexible and replicable model can be rolled out across catchments with limited resourcing. Combining measures of both demand and supply gives a richer basis for estimating likely use.

DETAILED PROPERTY ANALYSIS

The second component of the methodology is an analysis of D&S use at a detailed property and sub-catchment scale. This tier examines likely demand based on visual and automated interrogation of Geographic Information System (GIS) data and aerial photography. This approach involves a finer level of discrimination between drivers of demand and modes of supply. This helps validate and critique the results of the high level model. The detailed approach involves three main tasks:

1. Detailed land use analysis at the property scale to assess the proportion of the land area used for grazing, irrigation, forest or 'other' purposes (e.g. houses, farm sheds). This involves analysis of high-quality (50cm rectified) aerial imagery available. The majority of the catchment area is subject to a visual land use assessment. This includes all houses on private D&S land greater than 0.4ha and not connected to reticulated supply, and grazing estimates on all D&S land greater than 2ha. A high level of time and resources is required to implement this detailed approach at the property scale, but the aerial examination could be undertaken at a slightly coarser scale if required.
2. A demand profile of domestic, curtilage, stock and dam losses is formulated at the individual property scale. This is based on the land use analysis and incorporates the number of houses and proportion of grazing area in the demand calculations. Losses from D&S dams include losses due to evaporation and seepage.
3. Supply side analysis at the property scale from the combination of available D&S sources, including dams, groundwater bores and/or waterways via direct access or off-stream watering. These

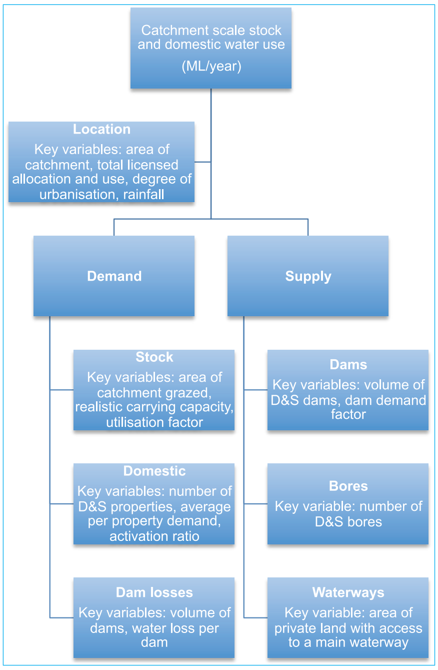

Figure 2. Schematic representation of high-level stock and domestic model.

Table 1. Overview of key catchment information.

Catchment	Licensed allocation (ML)	Bulk entitlement (ML)	Area (km^2)	Average annual streamflow (ML)	Number D&S properties[5]	Density of D&S properties (properties/km^2)	Proportion of catchment grazed (%)	Proportion of public land (%)
Little Yarra	1,357	-	154	43,000	256	2	25%	65%
Don	145	-	21	4,700	48	2	20%	62%
Olinda	780	-	81	20,600	481	6	10%	31%
Plenty	672	-	348	23,880	1,682	5	30%	31%
Steels, Pauls & Dixons	1,799	-	128	4,700	516	4	20%	32%
Stringybark	2,709	-	77	12,300	559	7	30%	2%
Woori Yallock	9,548	-	363	85,000	838	2	31%	16%
Maribyrnong	5,457	9,920	1,430	125,400	4,152	3	40%	9%

are additional rather than exclusive rights, so a single property may make use of a combination of all of these sources.

LANDHOLDER SURVEY

The third tier involves ground-truthing via a landholder survey. This is used to validate the demand and supply characteristics of the catchment from the earlier approaches. This approach also allows an assessment of the seasonality of demand and some analysis of the drivers of choice between alternative sources. A purposive sample of landholders is taken from the catchment (De Vaus, 2002). Using a variety of methods, including telephone, web and mail, provides evidence to help adjust and calibrate the assumptions in the high-level model.

COMPARISON TO OTHER APPROACHES

The primary difference in the methodology developed for this study from traditional approaches is that the probable D&S consumption is calculated from known demand characteristics that can be validated rather than from standardised figures per unit of potential supply.

So, for example, the *Victorian Water Accounts* estimate D&S use to be 2ML/bore/year in groundwater areas in northern and western Victoria managed by Goulburn–Murray Water and Grampians Wimmera Mallee Water, and 1.5ML/bore/year in groundwater areas south of the divide managed by Southern Rural Water (DSE 2010b). This assumes that usage is based on a nominal supply volume per unlicensed or unregulated bore, and does not account for potential D&S use from waterways or dams. Furthermore, it does not consider highly variable use characteristics by catchment such as the area of the catchment grazed, realistic carrying capacity and the number and relative demand of D&S properties.

RESULTS AND DISCUSSION

THE CATCHMENTS ASSESSED

The study of D&S demand and supply was undertaken in eight catchments managed by Melbourne Water, seven in the Yarra Basin and one in the Maribyrnong. An overview of the licensed water use and key D&S demand by catchment is outlined Table 1.

The catchments fell into two broad categories:

- More rural, drier catchments with a higher proportion of D&S properties, such as the Maribyrnong and the Plenty; and
- More peri-urban catchments with higher rainfall and more licensed diverters, in the Yarra Basin.

The sections below report on the findings of the study under five main headings:

- **Demand findings:** What insights were gained around the factors that drive higher or lower demand;
- **Supply issues:** What variables were significant in terms of the availability and use of different forms of supply;
- **Farm dams:** The impact of farm dams and options for managing their impact;
- **Usage characteristics:** Evidence from the landholder survey;
- **Relative materiality:** How significant was D&S use and demand in comparison with streamflow and other sources of consumptive take?

Table 2. Key drivers of D&S demand.

Demand component	Key variable	How this affects D&S demand
Stock	Area of the catchment grazed	The larger the area of the catchment grazed, the greater the stock demand. This figure is highly variable, for example in the Woori Yallock catchment this was 31%, whereas the Don catchment was 20% obtained from the detailed approach.
	Commercial carrying capacity for stock grazing (dry sheep equivalent/ha)	The higher the carrying capacity the greater the stock demand. Carrying capacity is based on growing season, which is the number of months between the autumn break and when pastures go to seed.
	Utilisation factor	Not all grazing land is actively farmed to its capacity. Especially around urban fringes there is a tendency for land not to be used to its full agricultural potential.
Domestic (including curtilage)	Number of D&S properties (houses on private properties greater than 0.4ha not connected to town supply)	The higher the number of D&S properties the greater the domestic demand. This figure is highly variable. In urban areas this is low (due to potable supply), in peri-urban areas this is moderate and in rural areas this is high.
	Average per property demand for domestic usage from D&S sources of supply (i.e. dams, bores and/or waterways)	The higher the per-property demand for domestic usage the greater the domestic demand. In urban areas this is low, in peri-urban areas this is moderate and in rural areas this is high. The realistic estimate used in the lower limit of the high-level approach as well as the detailed approach is 0.4ML/house per year.
	Activation ratio	Not all large properties that are not connected to town water supply have a house on them. In high rainfall zones, many houses rely on rainwater tanks, and their full curtilage right is rarely utilised.
Dam losses	Volume of D&S dams (volume of all farm dams minus the volume of licensed and registered dams)	The greater the volume of D&S dams the greater the dam losses.
	Water loss per dam	This includes evaporation loss and seepage.

KEY DEMAND FINDINGS

Drivers of D&S demand

There are three main components to D&S demand; these are stock, domestic (including curtilage) and dam losses. As noted above, dam losses are included as part of the total demand assessment even though they do not represent an active consumptive use. The key variables of these D&S components are outlined in Table 2.

The analysis in Table 2 shows that the most variable components of total D&S demand are:

- The number of active D&S properties drives domestic and curtilage use. The number of D&S properties is directly proportional to the degree of urbanisation. Rural catchments have a higher number of D&S properties but a lower activation rate, while urban and peri-urban catchments have a smaller number of D&S properties, but a higher activation rate and also higher likelihood of town water supply;
- The area of the catchment grazed drives stock use. The larger the proportion of the catchment grazed, the greater the stock demand. The utilisation factor for stock demand is a function of urbanisation (lifestyle properties are not driven by commercial imperatives);
- Dam losses are a function of the volume of dams. These losses are very significant as they represent between 50% and 80% of total D&S demand.

Key findings

The analysis of demand data from the D&S studies showed that (RMCG, 2011; RMCG, 2012a; RMCG, 2012b; RMCG, 2012c):

- The density of overall D&S use ranged from 1 to 3ML/km^2/year at a catchment scale:
  - Use was lower (1ML/km^2/year) in those catchments where there was a lower density of D&S properties (≤ 2 properties/km^2), moderate proportion of the catchment grazed (≤ 25%) and a high proportion of public land (≥ 60%)
  - Use was higher (2 to 3ML/km^2/year) in those catchments where there was a higher density of D&S houses (2 to 7 properties/km^2), greater proportion of the catchment grazed (20 to 40%) and lower proportion of public land (≤ 30%);
- Total D&S use in a catchment per D&S property ranged from 0.4 to 1.4ML/property/year;
- D&S dam loss ranged from 1 to 6ML/km^2/year;
- The ratio between stock and domestic use varied by catchment type:
  - In rural catchments it was one-to-one (i.e. equal between stock and domestic use)
  - In urban and peri-urban catchments it was one-to-two (S:D), i.e. domestic use was more important than stock demand in more heavily urbanised catchments.

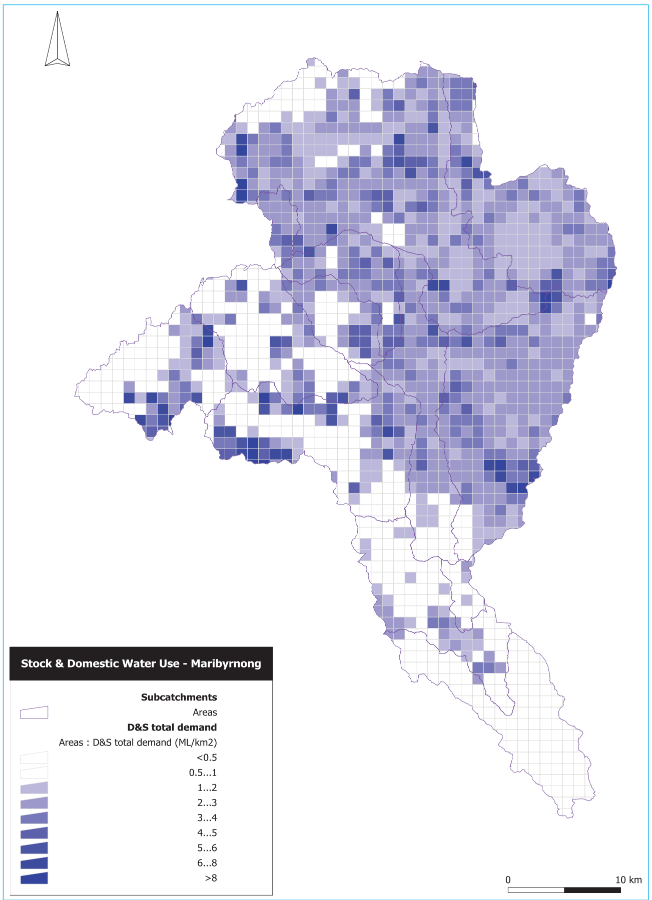

Figure 3. Total D&S use hotspots (ML/km^2) in the Maribyrnong catchment.

Hotspots mapping

A hotspots mapping technique was developed to provide a spatial representation of the density of stock, domestic and total D&S use within a catchment. An example is provided in Figure 3. The density of D&S use is based on the land use characteristics within a square kilometre matrix and the assumptions for key variables in the lower limit of the high-level model and detailed approach.

This mapping approach provides catchment managers with a rapid assessment tool to identify priority locations for further review.

KEY SUPPLY FINDINGS

This section reports on the analysis of the alternative sources of supply drawn on by D&S users.

D&S supply can include any combination of dams, groundwater bores and/or waterways via direct access or off-stream watering. These are additional rather than exclusive rights, so a single property may make use of a combination of all of these sources, as shown in Figure 4.

The analysis of supply data from the D&S studies showed that:

- **Stock:** 50 to 75% of stock water could be supplied from either dams or waterways

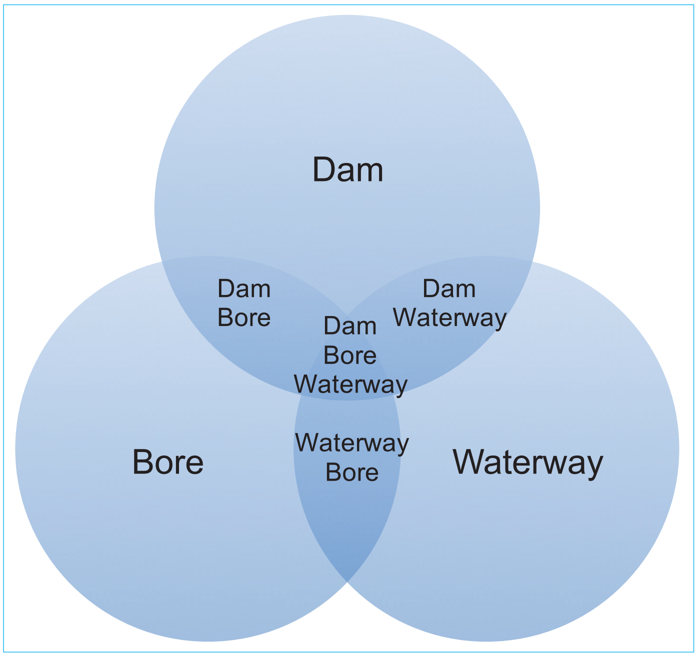

Figure 4. D&S supply options on a property.

Table 3. Intensity and demand of D&S dams.

Catchment	D&S dam loss intensity (ML/km^2)	Dam losses as a proportion total D&S demand (%)
Little Yarra	2	66%
Don	1	49%
Olinda	3	60%
Plenty	6	75%
Steels, Pauls & Dixons	5	74%
Stringybark	6	68%
Woori Yallock	5	60%
Maribyrnong	6	79%
Average	4	66%

based on available sources of supply at the property scale. However, the landholder surveys suggested that most stock watering is likely to come from dams;

- **Domestic:** 20 to 50% of D&S properties do not have access to a dam, bore or waterway to supply domestic needs. In this case, domestic water is most likely being sourced from rainwater tanks, which have the capacity to supply the majority of domestic needs;
- Bores provide a minor source of D&S supply;
- Waterways were little used as a source of D&S supply.

SUPPLY AND DEMAND FROM D&S DAMS

Dams play an important role in D&S supply and demand. D&S dams contribute a large proportion of the D&S supply, ranging between 65% and 80% of the total take.

Dam losses were consistently equal to or greater than the total volume of active D&S use across the catchments sampled (RMCG, 2011; RMCG, 2012a; RMCG, 2012b; RMCG, 2012c). These dam losses are not included in the traditional assessment of D&S use. The intensity of D&S dam losses ranges between 1ML/km^2 to 6ML/km^2 across the catchments, representing between 50% and 80% of the total D&S demand (Table 3).

This analysis suggests that D&S dams should be the priority target for future programs as they represent the largest single component of total D&S demand.

A number of alternative approaches could be adopted to reduce their impact on total catchment flows, including:

- Restriction on the construction of any new dams;
- Retirement of existing dams to reduce current interceptions;
- Incentive programs that seek to minimise the effect of current dams by, for example, re-profiling to reduce their size and surface area and improve water retention through lining, or low-flow bypasses.

Estimating the impact of farm dams on stream flows is challenging. The standard approach is to attribute an annual 'demand factor' to each dam that represents the percentage of the dam volume that is consumed each year. Traditionally this 'dam demand factor' has been set at a figure of 40–50%. In practice, the 'dam demand factor' in the Yarra Basin catchments could be as low as 10% due to the large number of small aesthetic dams and the urbanised nature of the region. This figure is supported by a D&S study undertaken in the Werribee catchment, which found an annual dam demand factor of 8% (Lowe *et al.*, 2009).

Dams being built on smaller properties will generally have a lower demand factor as they are built largely for aesthetic value rather than for commercial watering. Dams that have lower demand factors will remain at a higher level during more of the year. As a result they will intercept and capture less run-off. This may reduce the impact on streamflow. However, the greater volume means a larger surface area and so an increased rate of evaporation.

From a resource management planning perspective a more accurate dam demand factor could be useful in determining demand limits and interception levels, the justification or otherwise of new dam development. This would complement the SFMP process.

QUALITATIVE USAGE CHARACTERISTICS

The landholder survey provided validation of the demand and supply characteristics of the catchment, as well as evidence on qualitative usage characteristics. The key messages from a number of landholder surveys were:

- The majority of properties with a material D&S demand in the Yarra Basin catchments were used for lifestyle/small acreage purposes, whereas in the more rural catchments in the west (Maribyrnong) grazing was the predominant land use. This influenced how landholders accessed water for D&S purposes;
- Cattle, followed by sheep and horses, were the predominant stock type grazed in the catchments;
- Stocking rates were generally below standard commercial carrying capacity (Saul & Kearney, 2002);
- Rainwater was the primary source of domestic water, while dams were the primary source of stock water. However, rainwater was used as a supplementary source for stock;
- A number of properties have access to waterways via direct access and off-stream watering; however, this is underutilised and held as a supplementary source of D&S supply;
- Dams, bores, waterways, rainwater tanks and town supply are used year-round to supply water for household and garden purposes;
- All sources were used year-round for stock watering purposes. Supplementing sources such as waterways, bores and town supply were all identified as being used in summer, as were dams and rainwater tanks. Landholders may supplement their primary source of stock water with these sources during the drier months.

MATERIALITY OF DEMAND

The section reviews the evidence on the relative materiality of D&S demand when compared with annual streamflow and other sources of consumptive demand. In this section the term 'D&S use' reflects only active consumptive use and excludes dam losses, because this places the estimate on a consistent basis with the published figures for diversion licences.

Active D&S use represents approximately 2% of average annual stream flow, ranging from less than 1% to 5%. Clearly if dam losses were included in the usage estimate then the percentage would at least double. However, even a total of 5% is unlikely to represent a major impost on ecosystem functionality, particularly as the 'take' occurs year-round and is not concentrated in summer months when flows are lower.

The relative materiality of D&S use in proportion to other forms of extraction

Table 4. Comparison of D&S use to average annual stream flow, licensed allocation and bulk entitlement.			
Catchment	Proportion of average annual stream flow (%)	Proportion of licensed allocation (%)	Proportion of bulk entitlement (%)
Little Yarra	0.4%	12%	-
Don	1%	17%	-
Olinda	1%	22%	-
Plenty	3%	110%	-
Steels, Pauls & Dixons	5%	12%	-
Stringybark	2%	8%	-
Woori Yallock	1%	12%	-
Maribyrnong	2%	43%	24%
Average	2%	30%	-

varies by catchment. The following analysis compares D&S use with water taken under a Section 51 Diversion Licence or as part of a bulk entitlement (as shown in Table 4). D&S use was proportionally lower (8–22%) in those catchments with a relatively high volume of licensed allocation, in high rainfall zones in the Yarra Basin (Little Yarra and Don, Olinda, Steels, Pauls & Dixons, and Stringybark). By contrast, D&S use was proportionally higher (>40%) in drier rural catchments where there are relatively low licensed volumes (Maribyrnong, Plenty).

LESSONS AND NEXT STEPS

The study demonstrates that a simple methodology can be employed to generate robust and defensible evidence on likely D&S demand by catchment. This approach is more reliable than traditional approaches based on extrapolation from the sources of supply, and can be applied on a consistent basis across catchments.

The outcomes of this study and others will form the basis of Melbourne Water's new Unregulated Rivers program. This program will address water uses not covered by Stream Flow Management Plans. The program lacks the statutory nature of Stream Flow Management Plans and will rely primarily on engagement, education and possibly financial incentives where value-for-money can be demonstrated.

The key findings of this study that will shape the structure of the program are:

- Evaporative losses from unlicensed dams exceed active D&S use in most catchments. These losses should be a priority target for future work;
- A dam has proportionally more impact on stream flow in drier catchments in the north and west than wetter catchments in the east;
- D&S demand in peri-urban areas is likely to be low due to reduced demand for stock watering and the reliance on rainwater tanks for domestic demand;
- Traditional estimates of D&S demand have relied on an extrapolation from the number of groundwater bores. This approach generates an over-estimate of likely overall demand;
- D&S water use can be significant compared with licensed allocation in drier catchments that do not support intensive horticulture.

The study is validated by others that indicate that unlicensed D&S water use can have an impact on stream flows and needs to be addressed to protect the riparian environment and security of other users (SKM, 2011). Because water use under Section 8 of the *Water Act 1989* (Vic) is unlicensed, any change program will need to be addressed by engagement and education rather than regulation, as is the case with licensed use through Stream Flow Management Plans.

These messages will need to be articulated to and accepted within the community for the impacts of D&S water use to be effectively addressed. The program will engage the community through empowering 'early adopters' and local organisations.

Articulating the main findings to the community will be supported by case studies that demonstrate the findings and benefits of addressing D&S demand and supply issues at the property scale. A key message will be that addressing these issues improves individual users' security of supply, as well as environmental outcomes. The program will rely on existing community contacts established through successful river health programs that fund physical works such as revegetation and weed removal.

Case studies may take place at the scale of an individual property or at a larger subdivision or sub-catchment scale. For example, if it can be demonstrated that a landowner replacing their dam supply with rainwater tanks would have a measurable impact on downstream flow, Melbourne Water may provide funds to help. Alternatively, the fire fighting supply for a new subdivision could be a bore with a tank and standpipe or a single deep and readily accessible dam, rather than small and unreliable individual property dams.

Initial case studies will be accompanied by intensive monitoring efforts to quantify their benefits. It is hoped that these case studies will help to engage others to identify similar solutions across the catchment in question. Before any widespread adoption of financial incentives, a rigorous cost-benefit analysis of on-ground works will be required.

THE AUTHORS

Carl Larsen (email: carll@rmcg.com.au) is a Socio-Environmental Scientist at RMCG. He works in integrated water resource management, evaluation and planning of natural resource management programs, climate change and stakeholder engagement.

Matthew Toulmin (email: matthewt@rmcg.com.au) is a Water Economist and Policy Analyst, and **Duncan Wallis** (email: duncanw@rmcg.com.au) is a Water Resource Engineer, both at RMCG.

Bill Moulden (email: bill.moulden@melbournewater.com.au) and **Sarah Gaskill** (email: sarah.gaskill@melbournewater.com.au) are Environmental Flows Planners and **Anna Lucas** (email: anna.lucas@melbournewater.com.au) is Acting Manager Environmental Flows, all at Melbourne Water.

REFERENCES

Ceena PB (1983): Victoria's Water Frontage Reserve, Department of Crown Lands and Survey, Melbourne.

Department of Primary Industries (2010): Livestock Drinking Water Requirements Guidelines, March, Ellinbank.

De Vaus DA (2002): Surveys in Social Research Fifth Edition, Allen & Unwin, Crows Nest.

Department of Sustainability and Environment (2002): Notes on Aesthetic Dams, *Water Act 1989*.

Department of Sustainability and Environment (2008): Climate Change in Port Phillip and Westernport, Victorian Climate Change Impacts Program, East Melbourne.

Department of Sustainability and Environment (2010a): Guidelines for Domestic and Stock and Aesthetic Dams – Calculating Reasonable Use, December, State Government of Victoria, East Melbourne.

Department of Sustainability and Environment (2010b): Victorian Water Accounts 2009–10; A Statement of Victoria's Water Resources, State Government of Victoria, Melbourne.

Department of Sustainability and Environment (2011): Victorian Water Register, Take and Use Licence and Registration Licence Statistics, waterregister.vic.gov.au/Public/Reports/WaterLicenceStatistics.aspx

DGC and SKM (2009): Domestic and Stock Assessment of the Campaspe Basin; Determination of Reasonable Domestic and Stock Allowance, 10 July, Melbourne.

Environmental and Health Council of the Australian Government (2004): Guidance On Use Of Rainwater Tanks.

Larsen C, Wallis D, Toulmin M & Gaskill S (2012): The Importance of Estimating Stock and Domestic Water Use in the Context of a Water Constrained Future – Lessons from the Woori Yallock Catchment, Victoria, Water and Climate: Policy Implementation Challenges; Practical Responses to Climate Change National Conference proceedings, Canberra, 1–3 May 2012, Barton, A.C.T.: Engineers Australia, 2012: pp 208–215.

Lowe L, Vardon M, Etchells T, Malano H & Nathan R (2009): Estimating Unmetered Stock and Domestic Water Use, 18th World IMACS / MODSIM Congress, Cairns, Australia, 13–17 July.

Melbourne Water (2012): Draft Healthy Waterways Strategy; A Melbourne Water strategy for managing rivers, estuaries and wetlands, October, Melbourne.

National Water Commission (2010): Position Statement on Intercepting Activities, May, Australian Government, Canberra.

RMCG (2011): Stock and Domestic Water Use in the Woori Yallock catchment: Estimating usage, October, Report prepared for Melbourne Water.

RMCG (2012a): Stock and Domestic Water Use Estimates: Little Yarra and Don Catchments, April, Report prepared for Melbourne Water.

RMCG (2012b): Stock and Domestic Water Use Estimates: Maribyrnong Catchment, July, Report prepared for Melbourne Water.

RMCG (2012c): Stock and Domestic Water Use Estimates High-Level Approach Olinda, Plenty, Steels, Pauls & Dixon and Stringybark Catchments, October, Report prepared for Melbourne Water.

Saul GR & Kearney GA (2002): Potential Carrying Capacity of Grazed Pastures in Southern Australia, *Wool Technology Sheep Breeding*, 50 (3), pp 492–498.

SKM (2009a): Improving Estimates of Farm Dam Distributions and Attributes in Victoria, Melbourne.

SKM (2009b): Domestic and Stock Assessment in the Campaspe Basin.

SKM (2010): Review and Update of REALM Model and Scenario Modelling, Melbourne.

SKM (2011): Farm Dam Impacts in the Maribyrnong Catchment – Update, Report prepared for Melbourne Water, December.

The Public Land Consultancy (2008): A Review of Management of Riparian Land in Victoria, Melbourne.

HPH