Journal of Hydrology 552 (2017) 807–820

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Developing a water market readiness assessment framework

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ARTICLE INFO

Article history:
Received 6 April 2017
Received in revised form 6 July 2017
Accepted 7 July 2017
Available online 14 July 2017

Keywords:
Water trading
Water markets
Assessment framework
Murray-Darling Basin
Demand management

ABSTRACT

Water markets are increasingly proposed as a demand-management strategy to deal with water scarcity. Water trading arrangements, on their own, are not about setting bio-physical limits to water-use. Nevertheless, water trading that mitigates scarcity constraints can assist regulators of water resources to keep water-use within limits at the lowest possible cost, and may reduce the cost of restoring water system health. While theoretically attractive, many practitioners have, at best, only a limited understanding of the practical usefulness of markets and how they might be most appropriately deployed. Using lessons learned from jurisdictions around the world where water markets have been implemented, this study attempts to fill the existing water market development gap and provide an initial framework (the water market readiness assessment (WMRA)) to describe the policy and administrative conditions/reforms necessary to enable governments/jurisdictions to develop water trading arrangements that are efficient, equitable and within sustainable limits. Our proposed framework consists of three key steps: 1) an assessment of hydrological and institutional needs; 2) a market evaluation, including assessment of development and implementation issues; and 3) the monitoring, continuous/review and assessment of future needs; with a variety of questions needing assessment at each stage. We apply the framework to three examples: regions in Australia, the United States and Spain. These applications indicate that WMRA can provide key information for water planners to consider on the usefulness of water trading processes to better manage water scarcity; but further practical applications and tests of the framework are required to fully evaluate its effectiveness.
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1. Introduction

The supply of fresh water is finite and, in many locations, sufficiently scarce such that it is not possible to satisfy all competing uses. The challenge of reconciling supply and demand will intensify as global water extractions are expected to increase 55% by 2050 (WWAP, 2014). This raises concerns about future trends in global water security; defined as the ability to safeguard access to water for livelihoods and development, to protect against water pollution and water-related disasters, to preserve ecosystems, and to help ensure peace and political stability (UN Water, 2013). At the very least it requires approaches to water governance that explicitly acknowledge the need to manage risks and to live within bio-physical limits, even if the precise management approaches are contested (Garrick and Hall, 2014).

There are two diverse arrangements for dealing with water scarcity risk and reallocation: demand-side management and supply augmentation. Demand-side management includes educational measures (e.g. providing information on how to decrease water-use in homes/farms), regulatory and/or planning processes (e.g. legislative change coupled with catchment water-sharing plans or restrictions) and economic incentives (e.g. pricing to discourage over-use, the use of subsidies that increase technical water-use efficiency, and/or arrangements that allow the trading of limited opportunities to use water). Supply augmentation (e.g. further dam and weir construction) or substitution (e.g. desalinated water) has traditionally been used and promoted by managers because it offers a technical and relatively rapid 'fix' to address demand gaps. Ideally, both demand and supply responses should be integrated, but this is frequently not the case, highlighting the need for governance arrangements that better coordinate water demand and supply (Sadoff et al., 2015).

Three main water reallocation approaches are usually discussed in the literature: administrative, collective negotiations or

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http://dx.doi.org/10.1016/j.jhydrol.2017.07.010
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agreements and market-based transfers (Meinzen-Dick and Ringler, 2008). Market-based reallocation may be unsuitable for developing economies due to less-clearly specified, distributed and prioritised water rights; uncertain operational rules; inadequate or disconnected supply and distribution infrastructure and poor water source, supply, usage and measurement data; and unequal access to the rule of law. In such places, less complex and costly non-market reallocation approaches may be more suitable (Marston and Cai, 2016); especially where a priority is placed on equity and delivery of water to the poor and vulnerable rather than efficiency considerations. However, in many developed economies growing water scarcity, greater environmental concern and limited supply-side options have driven an increased emphasis of demand-side reallocation policies, especially water pricing, charges and markets. Often, the establishment of the conditions that enable efficient trading and the eventual full emergence of markets is more accidental than planned (Griffin, 2006). Proponents of water markets argue they offer more efficient and effective approaches to reallocate water, and can also protect social and environmental values (e.g. Chong and Sunding, 2006; Crase and O'Keefe, 2009). By contrast, others suggest markets commodify water to benefit the wealthy and powerful at the expense of the most vulnerable, their communities or the environment (Barlow and Clarke, 2005). Market power, especially in economies where there are gross income inequalities, can drive negative perceptions of markets as a well-accepted means of reallocating water (Easter and Huang, 2014) and also increase the transaction costs to achieve market arrangements. Debate about water markets has also occasionally focused on the privatisation of urban water supplies (Goldman, 2007; Segerfeldt, 2005). Regardless of the viewpoint, achieving water security remains a major global challenge, and for this reason water markets still remain a possible policy response.

To address the water scarcity challenge, useful general frameworks exist for comparing water institutions (e.g. Dinar and Saleth, 2005) and also for proposing improvements to water market implementation and performance. These relate to issues of effective legal property rights (Tan, 2005), exchange frameworks for efficient transfers (Griffin, 2006), initial implementation recommendations (Maestu and Gómez Ramos, 2013) and agendas for comparison and performance evaluations across different water market contexts (Grafton et al., 2011). Nevertheless, despite significant attention devoted to the study of water rights/markets there is, until now, very little practical guidance to evaluate the appropriateness of water markets in emergent or semi-developed situations (Young, 2014b). Given the multi-decade experience of water markets in a number of countries, it is timely to distil insights about markets as a response to water scarcity. For the first time in the literature, we provide a framework that identifies the conditions necessary to facilitate reallocation via water trading; where that arrangement is perceived as an appropriate strategy. Our intent is for the framework to be used by water managers and planners to identify possible barriers to the implementation of water markets. In so doing, we stress that we do not propose water markets as a universal solution for the multidimensional problems of water security.

2. Conceptual background and water market development factors

2.1. Water trading

Water trading can be defined as the voluntary buying and selling of water in some quantifiable form; either in the present or future. In essence, there are three types of water trading: i) short-term or temporary transfers of water that is already allocated and available for immediate use; ii) medium-term leasing of water allocations in a manner that enables a water user to plan secure access to water for a period of time; and iii) permanent transfers of water entitlements – the on-going property right to either a proportion or fixed quantity of the available water at a given source. Water trading arrangements can range from informal arrangements between neighbours (Maestu, 2013; Shah and Ballabh, 1997); to formal recognition and management by governments and/or communities. Formal government and/or community sanctioned water trading arrangements involve a variety of rules and processes designed to protect the interests of all users, including third parties who might otherwise be adversely effected (NWC, 2011a,b). The formal trade of water thus has a number of possible benefits; including that it can help ensure that water-use costs (and its opportunity costs), are explicitly accounted for by water users.

A key challenge for those interested in the role of water trading in helping to manage water-use is the fact that water is an 'uncooperative' commodity (Bakker, 2005, 2007). Its value is derived not only from its quantity, but also its quality, reliability, timing, and location and use. In many cases, trade involves re-allocation: sometimes only to a neighbour as mentioned above, but increasingly to other sectors and even other regions (Grafton et al., 2011). Trade can, and often does, change who, where and how water is used, which can affect subsequent extraction by downstream parties or future use of aquifers. Thus, changes in the location, timing and technical efficiency of water-use matter (Bauer, 2004; Easter et al., 1999; Howe et al., 1986; Young and McColl, 2009), as does the costs of trading and enforcing water rights (Garrick et al., 2013; McCann and Easter, 2004) and the effects on non-consumptive uses such as transport, hydro-power generation and the environment.

Considerable progress has been made in the development of water trading and marketing arrangements. Countries such as Australia, the United States, Chile, Mexico, South Africa and China are increasingly using water trading and marketing arrangements to improve water-use. Despite this progress, the expanded use of formal water trading and marketing arrangements remains highly contentious. The complexity of water trade in wider social-ecological systems also means that trading is not able to comprehensively resolve all socio-economic issues around water-use (Meinzen-Dick, 2007). Indeed, Grafton et al. (2016) provide a critical review of the arguments for and against water trading, but conclude that while both social and environmental goals are compatible with water markets, careful design and effective oversight are required for any broader jurisdictional application.

2.2. Necessary conditions

The capacity of water access and allocation arrangements to allow water trading critically depends on local circumstances, the range of future scenarios (and the extent to which they can be known) and the available regulatory architecture (Maestu and Gómez Ramos, 2013). For example, it is common not to control or limit the extraction of water for livestock watering, but access arrangements for cropping can vary enormously by location. Thus, differences in approaches to water trading across locations requires an assessment of what works, and under what conditions (Easter and Huang, 2014).

There are many institutional factors that should be considered when governments contemplate the establishment of water entitlement and allocation regimes. Institutional arrangements necessary to enable efficient and equitable water trading should be in place well-before scarcity is realized, to prevent over-allocation. Proactive management of water resources can be achieved by early institutional investments in resource measurement, data collection and governance capacity. Consequently, many of the modifications and enabling conditions required to establish and sustain water markets are also issues associated with sound water resource governance generally.

Matthews (2004) highlights ten questions relevant for any discussion about the establishment or reformation of any water rights system, which have significance for water managers interested in subsequent market adoption. These include: how any rights to water are currently specified, distributed and prioritised; whether existing rights are tradeable in nature, or if transformation would be required; how clear are current operational water-use rules, and can they assist/hinder transfers; how certain are we of our data on current source, supply, usage and measurement; how should we enforce change or compensate losers in the modifications proposed, and who will achieve this; and are all aspects of the system (e.g. groundwater interaction, return flows, losses etc.) accounted for in the design of water markets. Issues that might help to stimulate water markets are also discussed such as adopting uniform rights across all uses (but with heterogeneous use-reliability or preferences), increased water pricing, removing spatial limitations to use, and adopting a national registry system (*ibid*.). This highlights the need to design water rights and, if necessary, respecify them as part of an integrated reform agenda. When changes are required such that water trading efficiently and equitably retains water use within sustainable limits, then there may also be a need for institutional capacity-building and adaptive governance arrangements to ensure effective and sustainable implementation (Marino and Kemper, 1998).

The literature and practical experiences show that water markets are far from a simple panacea for water reallocation problems. Rather, they are often one of the more complex economic instruments to design, develop, implement and sustain over time. Based on the Australian experience of water markets, Young (2014a) offers six valuable institutional design principles: i) separate water access arrangements into their various component parts; ii) assign any policy instruments for specific purposes only, and do not use multi-instruments; iii) design instruments with hydrological integrity; iv) keep transaction costs as low as possible; v) assign risk to one interest group; and vi) ensure robustness of a system through proper accounting for water-uses. Although there remain relatively few examples of water markets around the world, and expected benefits from marketing are often unmet due to complex impediments, analyses of global water markets suggest that other essential prerequisites exist. These include: initial allocation transparency; legal clarity and certainty; administrative capacity to cope with changing use arrangements; and vertically and horizontally nested arrangements intended to keep institution costs as low as possible (Grafton et al., 2011). Further, Perry (2013) proposes an ABCD + F (accounting, bargaining, codification, delegation and feedback) list of requirements for effective water resource management. Unfortunately, inadequate institutional capabilities of many countries mean that the journey to water trading arrangements that adequately respond to water security will be long and arduous (Grafton et al., 2016), and firmly out of the reach of some developing nations until such issues are resolved.

The OECD (2015) developed a 14-point 'health' check-list for water resource allocation institutional design. Trading arrangements are last in this check-list, suggesting that major transformational reform may be initially necessary together with careful attention to sequencing, to avoid lock-in arrangements that make further transition to water trading arrangements politically difficult. Indeed, we argue that on-going debate about the merits, or otherwise, of water trading continues because the institutional arrangements used to manage water resources have not been adequately designed to manage water scarcity. As a result, naïve decisions to allow 'unfettered' water trade prior to the reconfiguration of the administrative arrangements to adequately manage water supply and demand can be damaging to, rather than supportive of, water security (Maestu, 2013; Young, 2014b). Moreover, immature governance arrangements have led to calls for the adoption of non-market approaches to reallocation in regions where water rights are poorly defined and/or institutional capacity is limited (Marston and Cai, 2016).

Alternatives to water markets exist, but may result in less sustainable and effective outcomes in the longer-term. Where environmental watering objectives increasingly feature in policy-making, market-based reallocation approaches offer attractive and practical means for future adaptation in the face of uncertainty insomuch as they offer management discretion over water-use. Like Garrick et al. (2009), we emphasise that additional enablers such as necessary administrative procedures, organisational development/capacity to affect transfers, and adaptive mechanisms to overcome legal, economic, cultural and environmental barriers are required.

We contend that a desire or need for marketing reallocation arrangements will grow naturally in many contexts from the adoption of administrative or collective reallocation arrangements; prompting an increasing practical requirement for a water market assessment framework. The numerous and complex barriers to water reallocation raised by Marston and Cai (2016) motivate the need for a water market framework that can be used by water managers and planners around the world. Such a common non-prescriptive framework to evaluate the appropriateness of water allocation arrangements to facilitate low-cost trading, and how they might be developed in differing contexts, has yet to be produced (Grafton et al., 2016). Our purpose here, therefore, is to provide a very first framework attempt to fill this important knowledge and practise gap.

3. Developing water markets further

3.1. Exploring the case of the most advanced water market in the world – the MDB

While we acknowledge the limits on transferability arising from contextual circumstances that allowed markets to flourish in Australia, lessons drawn from a jurisdiction with long-running and successful water rights/market arrangements may offer a basis for such a framework. In particular, the southern Murray-Darling Basin (MDB) trading arrangements are often held up as a model for the rest of world to follow (Perry, 2013).

The MDB comprises four Australian states and one territory: (Queensland (QLD), New South Wales (NSW), South Australia (SA), Victoria (VIC) and the Australian Capital Territory (ACT)). This basin is federally managed under joint-agreement. An independent Authority is responsible for Basin-wide planning, with states responsible for the issuing of entitlements and management of water use within agreed limits. Federal responsibilities, primarily through the Authority, include: setting, monitoring and enforcing water market rules; monitoring, evaluation and enforcement of the Basin Plan enacted in 2012; determining water allocations for the environment; and prioritising annual environmental watering (Hart, 2016).

Within-state water allocation trades (i.e. spot or temporary trade) have been occurring since 1983 in NSW and SA, and since 1987 in Victoria. Water entitlement (i.e. permanent) trades have been allowed since 1983 (SA), 1989 (NSW/QLD) and 1991 (VIC); with interstate trades possible since 1995 (Wheeler et al., 2014a). Water allocation trade has grown substantially in the MDB since agreements to unbundle water licences from land

(1994) and the introduction of a cap (1995) on further surface-water extractions and use. Agricultural producers, by far the biggest MDB water users (ABS, 2013), have become more accepting of water markets over time and found it beneficial to their business (Grafton et al., 2016). Reviews of the economic impact of water trading in the MDB have found it increased regional domestic product by AUD$4.3 billion during the last major drought (2006–2011) (NWC, 2012). Further, between 2000–01 and 2007–08, despite a 70% decline in MDB irrigated surface-water, water trade, changes in farm crop prices and other adaptation meant that the adjusted gross value of irrigated production only fell 20% (Kirby et al., 2014). Water trading is now widely used as a risk-management strategy (Nauges et al., 2016; Zuo et al., 2014), has been of considerable social and economic value to individual water users and to rural communities, and has resulted in positive environmental outcomes (NWC, 2012).

Expected negative trade impacts, such as reductions in regional spending, employment and public services as a consequence of permanently traded water out of districts via markets (Alston and Whittenbury, 2011) and stranded infrastructure assets, have largely been avoided in the MDB. Notwithstanding the successes of water trading in the MDB there are deficiencies or gaps that currently exist in the MDB which have arisen from current and historical policy that include: unnecessary trade barriers, the need for improved water market and weather information, limited types of water trade products, inadequate understanding of return flow impacts, and possible future lock-in of some enterprises, like perennial production systems (Grafton et al., 2016). Nevertheless, the southern MDB offers a valuable context from which to draw insights that assist in the development of a water market readiness assessment framework (Table 1).

3.2. Developing fundamental water market enablers

The first step toward developing a water market readiness assessment framework involved establishing a set of prerequisites and fundamental water market enablers, as derived from our literature review and other countries' water market experiences or knowledge. Table 2 summarises the fundamental issues to be considered, and provides some key examples of the questions that could be used by practitioners to evaluate the need for, and development paths toward, water markets. The resultant set of prerequisites have been transformed into a series of water market enabling and constraining factors; with the full set of relevant questions provided in Appendix A. The Appendix also provides further detail of prioritisation and key importance of specific issues, with five stars indicating high priority and importance for water trade to be successful, and one star indicating low priority/importance.

4. A water market readiness assessment (WMRA) framework

4.1. Developing the framework

After further refinement and discussion of the insights drawn from our literature review and knowledge, and considering issues relevant to developing countries with low institutional capacity, a conceptual Water Market Readiness Assessment (WMRA) framework that involved three key steps was developed (Fig. 1).

The first step of the WMRA (**Background Context**) is a scoping exercise that establishes the context of a proposed market such as planning considerations, and established resource knowledge that allows for a definitive cap or an initial allocation/extraction level. The importance of institutional capacity is critical in the first step, including careful consideration of: broad reviews of the status and maturity of water rights, governance and institutional capacity, the current level of infrastructure development and operational rules, and the availability and quality of water data. Where these are insufficiently progressed and do not meet minimum requirements (for example, those stipulated in Matthews, 2004), non-market reallocation arrangements may be more appropriate and further use of the framework should cease until better institutional capacity is developed. However, if deemed to be sufficient for market-based arrangements, then further steps may be taken.

The second step (**Market evaluation, development and implementation)** goes beyond simply considering capacity, and assesses the current institutional arrangements that support or impede trading (discussed further in Section 4.3). The third step

Table 1
Insights from the Australian experience in the development of water trading and marketing arrangements.

1. The legacy of prior licensing decisions can result in markets causing over-allocation problems to emerge in a manner that erodes the health of rivers, aquifer and ecosystems.
2. Transaction and administrative costs are lower when entitlements are defined using a unit share structure, and not as an entitlement to a volume of water.
3. Market efficiency is improved by using separate structures to define entitlements, manage allocations and control the use of water.
4. Early attention to the development of accurate licence registers is critical and a necessary precondition to the development of low-cost entitlement trading systems.
5. Unless water market and allocation procedures allow unused water to be carried forward from year to year, trading may increase the severity of droughts.
6. Early installation of meters and conversion from area based licences to a volumetric management system is a necessary precursor to the development of low cost allocation trading systems.
7. Difficulties will be encountered within communities to plan for (and believe in) an adverse climate shift, but water-sharing plans that account for a climatic shift to a drier regime must be developed.
8. The allocation regime for the provision of water necessary to maintain minimum flows, provide for conveyance and cover evaporative losses need to be more secure than that used to allocate water for environmental and other purposes.
9. Unless all forms of water-use are accounted for, entitlement reliability will be eroded by expansion of un-metered uses like plantation forestry and farm dam development, increases in irrigation efficiency, etc.
10. Unless connected ground and surface-water systems are managed as an integrated resource, groundwater development and substitution will impact on the future allocation (and use) of surface-water.
11. Water-use and investment will be more efficient if all users are exposed to at least the full lower bound cost (preferably the upper bound cost) of water supply. One way of achieving this outcome is to transfer ownership of the supply system to these users.
12. Manage environmental externalities using separate instruments so that the costs of avoiding them are reflected in the costs of production and use in a manner that encourages water users to avoid creating them.
13. Remove administrative impediments to inter-regional trade and inter-state trade.
14. Markets will be more efficient and the volume of trade greater if entitlements are allocated to individual users rather than to irrigator controlled water supply companies and cooperatives.
15. Equity and fairness principles require careful attention to and discipline in the way that allocation decisions and policy changes are announced.
16. Water markets are more effective when information about the prices being paid and offered is made available to all participants in a timely manner.
17. Develop broking industry and avoid government involvement in the provision of water brokering services. *Source: Adapted from* Young (2010)

Table 2
Identifying fundamental water market enablers.

Fundamental Issues	Key example questions to guide discussion/thinking
Property Rights/Institutions: Unbundled, individuals versus environment, risk assignment, adaptive etc.	Does legislation exist which gives a clear understanding of rights to water for individuals/corporations and other legal entities? If so, is the degree of attenuation clear, and which legislation (or pieces of legislation) are pertinent? Does institutional capacity exist in the country to allow robust, transparent and secure water reform?
Governance: Legislation, water sharing plans, information availability, water allocation announcements, compliance etc.	Are enabling resources (such as information, planning resources and registers) available, reliable, legitimate and trustworthy? Is the administrative culture and behaviour of those involved in making decisions respected and trusted?
Hydrology: Connected systems, salinity and water quality considerations, limit & consequences of breach → environment → end of system, do we know what we don't know etc.	Is the hydrology of the system well understood, well documented, monitored and reported on in a way that is supportive of trade and is sympathetic to: • The resource constraint, and • The extent to which the knowledge of the resource is complete?
Entitlement registers and accounting systems: Ownership, trading rules, tracking use	Does the supplier have the systems, resources and technology to monitor use, and to ensure use is within constraints, licence/entitlement conditions? Are the registers and accounting systems used to track and enforce compliance robust?
System Type: Regulated/unregulated, surface water/groundwater, connectivity etc.	What is the status of infrastructure and what are the costs of accessing water in the system, and at various parts of the system?
Adjustment: Heterogeneity → Gains from trade, societal pressures, early-mover advantage etc.	Is there a sufficiently diverse (potential) market for water-use in the system so as to facilitate trade (willing buyers and sellers with different use profiles in terms of value add per $ of water) and what is the likely magnitude of these gains (ex-transaction costs)?
Externalities	Are effective arrangements in place to maintain water quality, ensure environmental outcomes, facilitate navigation, hydro-power generation, etc.?

(**Monitoring and continuous review/assessment)** outlines a continual review and assessment of water trading in the pursuit of further gains as experience emerges. The importance of considering sequential steps for the successful development and implementation is noted by Young (2014b). Our approach is consistent with Young's sequential market steps, but what we propose is non-prescriptive—and therefore not necessarily sequential or mutually exclusive. That is, although the process may appear linear, in fact progress can be made in parallel or by entering the framework at any relevant stage where enabling conditions permit. Our three steps thus provide a logical order for assessing the necessary preconditions where they may not currently exist, and offer multiple entry/exit points for water managers/planners. A more detailed analysis of each step follows.

4.2. Step One: Background context

The first step involves an evaluation of current institutional, legislative, planning and regulatory capacity to facilitate and/or allow water trade (*Existing institutional*, *planning and property right arrangements*). We expect that for many countries, institutional capacity is insufficiently progressed and does not meet minimum requirements to be able to proceed with water market reforms. Effective water trading arrangements fundamentally require a clearly specified set of entitlement and allocation arrangements that are monitored and enforced. Arguably one of the first administrative challenges is to establish a regime that ensures that water users can understand their entitlements and how to transfer them. This is challenging if the current situation involves significant over-extraction/consumption. Ideally, the water governance arrangements should: i) fully specify each share of the resource in perpetuity while allowing for changes in the proportion allocated to each share; ii) define the opportunity to use water in an unambiguous manner that fully assigns responsibility for managing supply risk to users; iii) be enforceable and ensure that the only way one user can access more water is to convince someone else to use less water; and iv) keep transaction costs as low as possible.

Water scarcity is a common motive for implementing water markets (Easter et al., 1998). Thus, in addition to institutional capacity issues, a clear calculation and definition of the total resource pool available for consumptive use, and how that may change over time (*Hydrology Considerations and System Type*), needs to be conducted (Freebairn, 2005). This should be combined with clear rules for the allocation of that defined resource pool.

4.3. Step Two: Evaluation, development and implementation

Effective water market governance includes the separation of regulatory, policy, commercial and operational functions associated with the water resource(s) in question. It also includes clear and consistent trading rules, as well as compliance and enforcement mechanisms (NWC, 2011a). There must also be a sufficient volume of exchange to overcome potential inefficiencies. Hence, the second step of the framework is to assess the *Potential benefits of trade*. For example, there has to be consideration of the number of individuals involved, the homogeneity of water-use, the potential benefit from trade and changes in water-use behaviour that can be derived, the direct costs associated with the governmental and institutional policy reforms necessary to enable trade, and the transaction costs associated with implementation and ongoing use. When the results suggest that there are significant net benefits, then this information needs to be packaged into two narratives: one that can be understood by the public and a second much more comprehensive narrative for consideration by professional analysts and those likely to be involved in facilitating implementation.

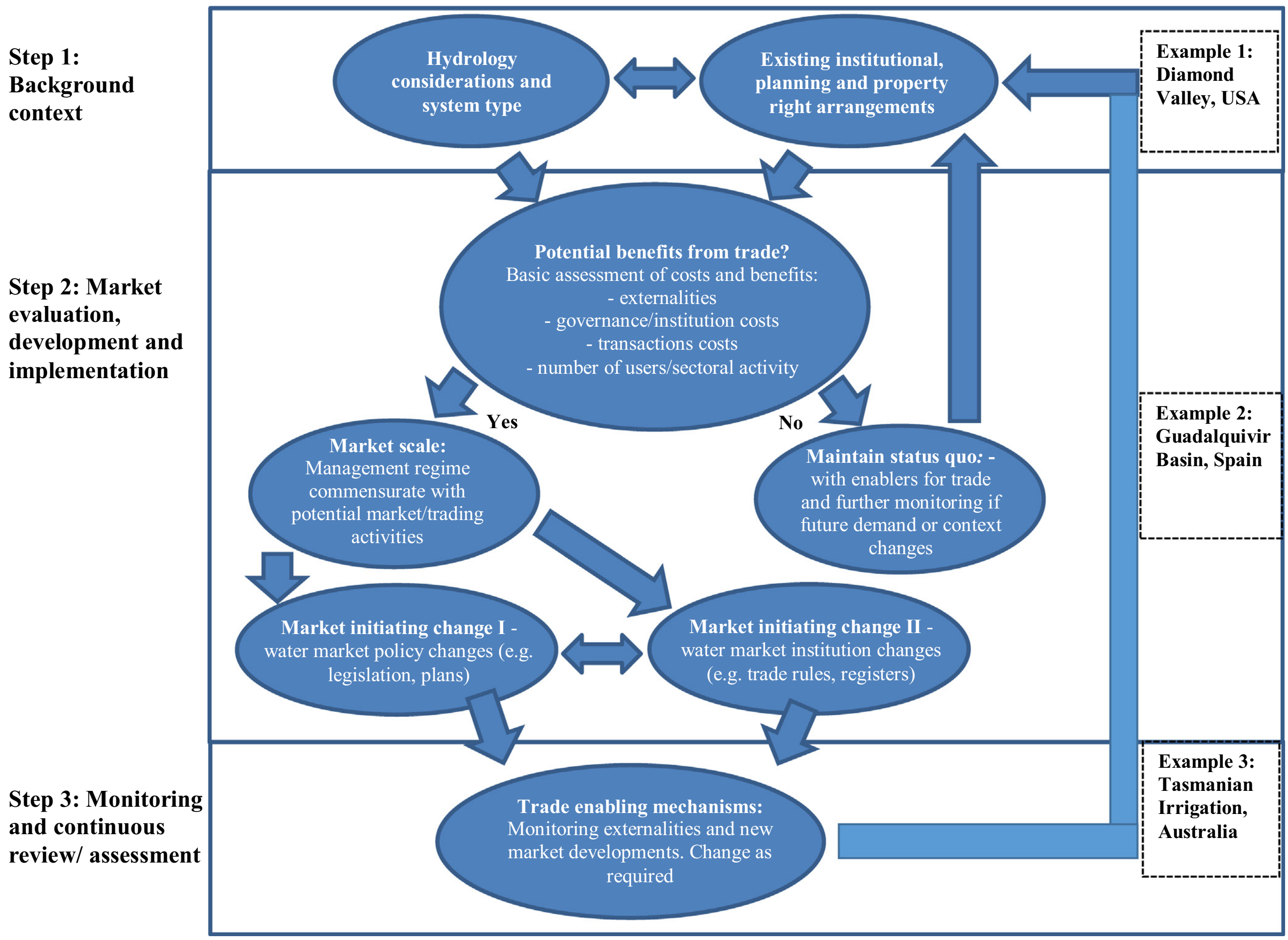

Fig. 1. Conceptual assessment approach for considering the readiness of jurisdictions for water markets.

Other reallocation inhibitors include high trade and transaction costs (for example, where participants are charged very high costs to transfer entitlements or allocations or face extremely long processing times to do so). There may also be price-setting influences as a result of limited competition among market participants; and potential externalities where the buyers and sellers do not exclusively enjoy and incur all of the benefits and costs (respectively) associated with trade. If a critical trading volume and benefit can be achieved, there may be scale economies associated with broader market implementation. This involves a move to *Market initiating change I* in Fig. 1, where broader legislation is put in place to allow for water reform, which then leads on to *Market initiating change II* where more detailed water reform leads to improvements like registers and clearer trade rules. If the assessments at Step 2 points to modest gains from trade, then the best policy for water managers/-planners may be to *Maintain the status quo*, but at the same time to instigate enablers for trade (which would allow transfers between a small number of individuals but not a fully functioning water market per se) back at Step 1's *Existing institutional, planning and property right arrangements*. Continual monitoring is also needed to assess future demand or context changes (which may move the planner to the sub-step of *Market initiating change I*).

4.4. Step Three: Monitoring and review

The development of water trading typically requires continuous monitoring, review and assessment whatever the stage of market development; but especially where it is to be sustained over the long-term. This mainly involves further development of the *Trade enabling mechanisms* in Step 3. This will include efforts to limit/reduce transaction costs, adapt to new information as it arises, and to scan for unanticipated externalities and opportunities for refined market products (e.g. option contracts or water banks) (Wheeler et al., 2013, 2014a,b). Such monitoring may, in turn, reveal additional changes to information sources or collection methods that then require legislative change, or new planning requirements/infrastructure projects to improve trade capacity (putting the planner back to review Step 1's *Existing institutional, planning and property right arrangements*).

Experimentation and adaptation is not uncommon in countries where water markets have been previously implemented (Maestu, 2013), and building flexibility into trading rules and procedures serves to enhance water security and management robustness; especially where risk needs to be accommodated along with future uncertainty (Garrick and Hall, 2014). It is also possible that flexibility in trading arrangements may provide opportunities for political intervention in the market. Thus, an appropriate balance between rule and process adaptation and surety is highly desirable. In the next section we explore applications of the framework in three examples to assess its practical usefulness in different circumstances.

5. Applied examples

Three location-specific examples to apply the framework were chosen based on several considerations. First, we focussed on jurisdictions where water markets are discussed as a possible means for responding to water security. Second, the particular regions reflect areas where water stress by 2040 as a ratio of withdrawals to supply is expected to be high (i.e. 40–80% (Maddocks et al., 2015)). Third, we chose countries at different levels of water market development, including: incomplete unbundling of land and water rights; uncertainty about water right definitions; unfinished catchment or water planning processes; limited time for development of trading rules; reluctance to cap extraction levels; an absence of water entitlement registers, water allocation accounts, inadequate metering, trading platforms, trade processing systems, market information; and/or a lack of administrative experience.

5.1. Applied Example One: Nevada's Diamond Valley, USA

The first example is the Diamond Valley area near Eureka in central Nevada (Fig. 2). This location has a tightly connected and rapidly-depleting groundwater resource, with no connections to other water resources. In addition, the community of water users is small and all the actors know one another.

Applying Step 1's *Hydrology Considerations and System Type* criteria, the Diamond Valley area contains a rich groundwater aquifer servicing irrigation, urban, mining and livestock uses. Current groundwater extraction rights of 160,354ML have been issued, with annual use estimated around 114,715ML, while the sustainable annual yield is estimated at just 43,170ML (hence indicating that around 70% of rights need to be retired to ensure sustainable water use). This over-use has resulted in aquifer declines of about 1–4 feet per year. Full aquifer depletion is expected in 30 years. Approximately 95% of committed water rights in the Valley are vested with primary or secondary irrigation farms. Initial plans to achieve a reduction in rights focused on payments to farmers who agreed to retire their rights, based on acreage and economic value calculations. No consistent or agreed value for the water was available, because no market existed. The estimated total cost of this program was USD$45 million over 50 years, dependent on assumed linear reductions over that period and farmers' willingness to participate (Hansford, 2014).

Fig. 2. Diamond Valley groundwater area.

In terms of Step 1's *Existing institutional, planning and property right arrangements*, water entitlements (rights) in the Valley are issued under the prior appropriation system where the oldest licences are assigned full allocations ahead of more recently issued (junior) rights. Also, under a current beneficiary-use requirement there is no incentive to innovate and ensure efficient water-use. If all the water assigned to a user is not used, then they risk the curtailment of that right, which incentivises over-consumption. Given the demand for extraction change and reductions in over-use, in 2015 the State Engineer decreed that all claimants to water rights (surface and groundwater) would need to provide proof to substantiate existing rights and that the community would have 10 years to prepare an approved groundwater management plan. If they failed to do so, the State Engineer would curtail water-use on the basis of seniority.

The threat of water regulation has helped in identifying that there are net benefits from trade and moving towards different reallocation systems. In terms of assessing Step 2 of the framework (*Net benefits of Trade*), commissioned studies in the Valley show evidence of significant gains from trade versus curtailment (e.g. Zeff et al., 2016). This reality, has provided the impetus to undertake the legal and institutional reforms necessary to make sure all existing property rights and arrangements are now conducive to trade. Consequently, the Diamond Valley plan is now well advanced, and in 2017 proposed a five-year process to convert all existing rights into tradeable shares; make annual allocations in proportion to the number of shares held; meter and enforce (with penalties) water-use; gradually curtail extraction to a sustainable level cap over a 30-year period; create a State Guarantee of share register and water account integrity; and implement efficient short-term trade; and management via a local governance board (Zeff et al., 2016).

The political and community acceptance of such a radical change in water governance was able to be achieved by allowing reversibility in the plan. For example, if at the end of five years if the community believed the new sharing regime to be inferior to the original priority regime, then all new shares would be cancelled and the old regime resumed (which is not expected). Summarising all this information in Table 3, and applying the WMRA framework, suggests that the Diamond Valley has progressed marginally beyond Step 1 toward the early stages of Step 2, with a range of market initiating changes still required to achieve market development.

5.2. Applied Example Two: Guadalquivir River Basin, Spain

Spain has often been identified in the literature as the blueprint for future water markets in the European Union (Hernández-Mora and del Moral, 2015). In particular, the Guadalquivir River Basin (GRB) in Spain is an interesting applied example as it is expected to play an important role in the country's water market development and expansion. The GRB has the country's longest river (Guadalquivir River – 666 km in length); spanning 12 independent provinces and four autonomous irrigation communities/regional governments (Fig. 3).

Demand is dominated by irrigated agriculture (89% used for both annual and perennial crops). Surface-water resources provide the bulk of supply (74%), supplemented by groundwater. Total consumptive water demand in the Basin is 3,845,100 ML per annum, while estimated average water resources are around 3,607,600 ML/year. Hence, water scarcity is a defining feature of the GRB which has historically been addressed through the construction of 65 interconnected dams and storages. There is no cap or closed basin arrangement, and thus new water concessions (rights) can still be granted and new irrigated zones planned. Consumptive water demand is dependent upon seasonal water availability and

Table 3
WMRA application summary.

Key Fundamental Market Assessors	Diamond Valley	Guadalquivir	Tasmania
Property Rights/Institutions			
1. Water Legislation	√	✓	✓
2. Unbundled rights	**X**	**X**	✓
3. Rights transferable	**X**	√	✓
4. Rights enforceable	✓	**X**	✓
5. Constraints between connected systems	✓	**X**	✓
Hydrology			
1. Documented hydrology system	✓	✓	✓
2. Understanding of connected systems	✓	✓	✓
3. Future impacts modelled	✓	✓	✓
4. Trade Impacts understood	✓	✓	✓
5. Resource constraints understood	✓	**X**	✓
6. Resource constraints enforced (e.g. existence of a cap/closed basin)	**X**	**X**	✓
Externalities/Governance			
1. Strong governance impartiality	✓	**X**	✓
2. Existence of externalities understood	✓	✓	✓
3. Water-use monitored	**X**	✓	✓
4. Water-use enforced	**X**	√	✓
System Type			
1. Suitability of water sources for trade	✓	✓	✓
2. Transfer infrastructure availability/suitability	✓	✓	✓
3. Regulation requirements for trade	**X**	✓	✓
Adjustment			
1. Gains from trade (no. users/transaction costs/diversity of use)	✓	√	✓
2. Political acceptability of trade	✓	**X**	✓
Entitlement registers and accounting			
1. Trustworthy systems	**X**	**X**	✓
2. Trade and market information availability	**X**	**X**	√
TRADE STEP REACHED	*Steps One to Two*	*Step Two*	*Step Three*

Note: In the table above a **X** indicates further reform required for that issue in the particular regional example; ✓ indicates that there is good evidence supporting that particular part of the assessment; while a smaller √ indicates that there is positive but still limited evidence, and thus room for improvement.

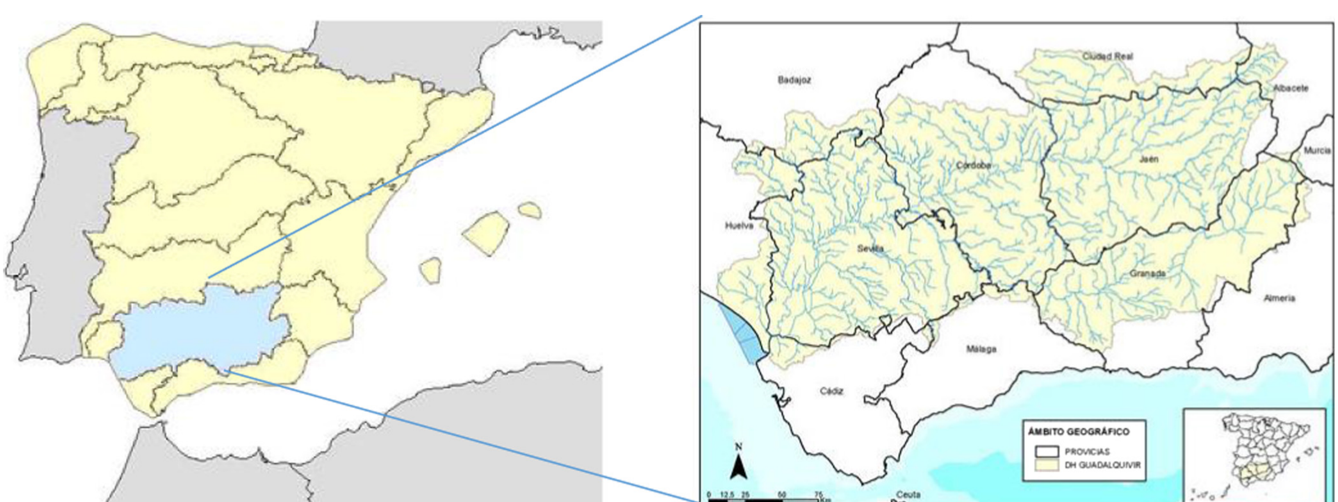

Fig. 3. Guadalquivir River Basin area.

proportional sharing rules based on priority classes (which meets some of the requirements in *Hydrology Considerations and System Type* in Step 1).

In terms of addressing key fundamentals of *existing property rights/institutions* in Step 1, irrigation water rights date back to the *1879 Water Act*, updated in 1985 to provide renewable legal rights for up to 75 years (which are still attached to land and managed by a Community of Irrigators under an 'administrative concession'). The need to address water scarcity and the benefits of potential water trade motivated *Law 46* in 1999, resulting in the introduction of temporary trade markets between Irrigation Community members on a limited scale (under requisite regulatory limits around use-type, location, extraction conditions and/or return flow requirements). Permanent sales of water without land are either not legally possible, and/or difficult to ratify through the collective-management arrangements. However, a significant impediment to trade has arisen from some historical decisions taken by the River Basin Authority, which have undermined the trust of some irrigation communities with regard to the security of their property rights. Uncertain right arrangements have thus curtailed involvement in larger-scale GRB trade, and reduced the benefits associated with transfers between hydrologically-interconnected irrigation communities.

In terms of assessing the *Net Benefits from Trade* in Step 2, while water charges and scarcity within communities have driven temporary trade and water bank trades since 1999, the scale of market trade remains low. Other trade-reducing influences include: i) agricultural user scepticism toward trading and socio-economic concerns about trade consequences; ii) irrigator substitution of surface-water for other sources such as groundwater, (although laws have been implemented to limit such substitutions, approximately 80% of groundwater users have not registered for a permit); iii) high transaction costs (lengthy times to assess and approve lease transfers, coupled with many conditional restriction requirements); and iv) lack of information and specialised trade platforms and/or third-party providers (Hernández-Mora and del Moral, 2015). However, the GRB's second water management Basin Plan (2015–2021) aims to review such water right issues, and may implement a range of further property right and institutional reforms. From the WMRA framework (Guadalquivir in Table 3) it is clear that despite water market objectives this applied example remains situated in a Step 2 loop, sitting between *Market initiating change I/II* and *Maintaining the Status Quo*. Although considerable effort has been put into trade-enabling mechanisms and arrangements, these are still not supported by separation of land and water property rights (*Institutional change*) and broader perceptions of property right security. In sum, the GRB is an example of a jurisdiction that is somewhat advanced in its water market development/implementation, but which has fundamental issues with governance impartiality and trustworthy systems. Before movement can be made towards permanent trade, the following issues need addressing: capping all GRB extraction (including groundwater) to be consistent with the EU's *Water Framework Directive*; separating land and water rights; and investments in property right security and institutional reforms.

5.3. Applied Example Three – Tasmanian Irrigation, Australia

The third example is in Australia, but outside the MDB. Tasmania is an island state to the south of the mainland with catchments that are hydrologically disconnected, creating independent allocation planning areas, diverse management arrangements and differing potential for water market development (Fig. 4). The state has a cool temperate climate that can vary widely regionally between

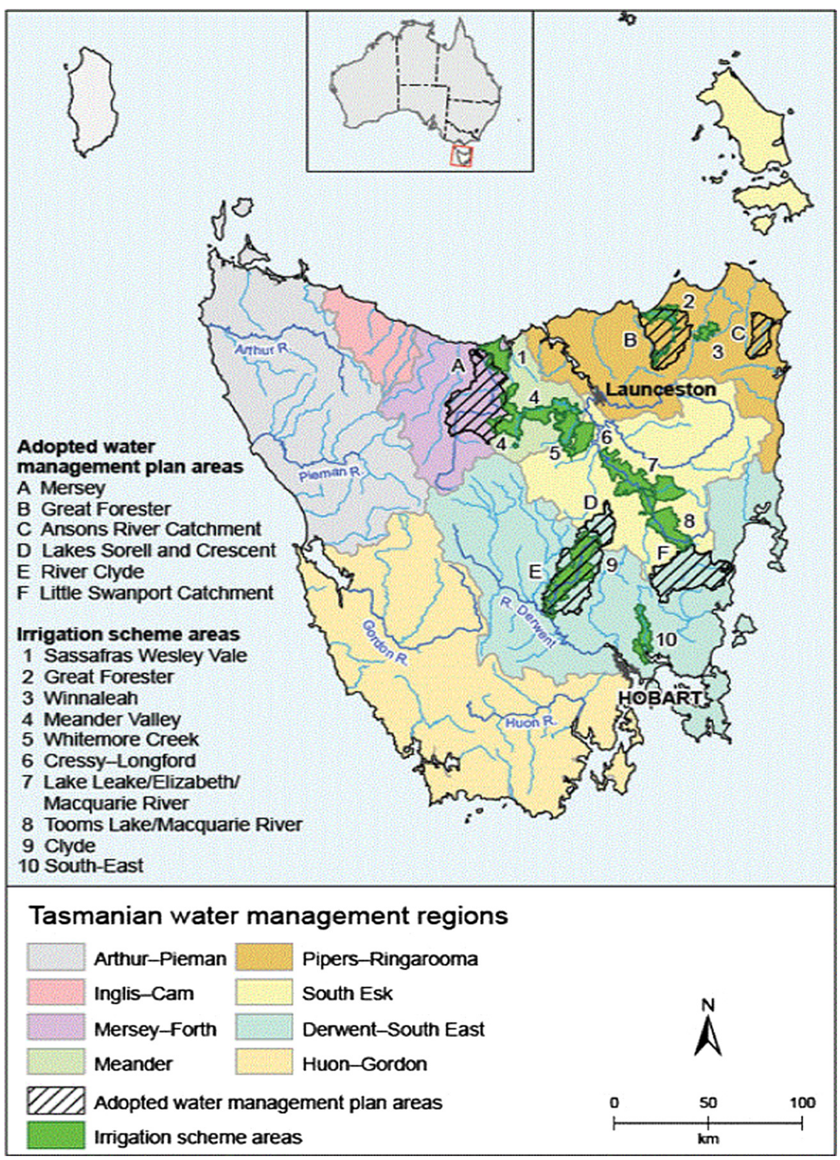

Fig. 4. Tasmanian Irrigation areas.

cold to hot extremes. Much of the state's irrigation districts are located on the eastern side of the island in regions where water capture, storage and delivery is possible.

In recent years, many new irrigation schemes have been proposed with the backing of state and federal grants to further economic development (as outlined by the *Tasmanian Water Development Plan*). This development objective is being achieved through public-private partnership arrangements (similar to past irrigation subsidy proposals experienced on mainland Australia) with a budget of AUD$220 million (Tasmanian Irrigation, 2012). Many catchments are not fully allocated, in the sense that water available for extraction/consumption exceeds current water entitlements. The exception is where hydro-electricity generation is present (NWC, 2013a).

In terms of assessing Step 1's key fundamentals of *Existing institutional, planning and property right arrangements* and *Hydrology Considerations and System Type*, Tasmania's state agencies are well advanced. They have developed surface-water and groundwater hydrological models, coupled with a freshwater ecosystem value database. This information provides sustainable yield and extraction catchment data, stress rankings and a management interface capacity (Tas DPIPWE, 2017). In addition, Tasmanian Irrigation (TI) used historical hydrology data tested against climate change runoff models developed by the CSIRO sustainable yields project (CSIRO, 2009) to help set scientifically-defined sustainable consumptive limits for each irrigation scheme (NWC, 2013b). Mandatory farm water access plans are used to ensure land is managed in accordance with the water development plan. Irrigation schemes have a projected 100-year life, and are planned to supply water at an average annual reliability of 95%.

Tasmanian planners are currently focussed on developing and supporting the institutions needed for water trade among affected stakeholders, particularly those in the agricultural sector. Water entitlement and allocation arrangements are being designed to facilitate water trading, as it was assessed that there were considerable *Net Benefits to be derived from Trade* (Step 2) because of the number of irrigators, the heterogeneity of agricultural production in the region, and future demand for Tasmanian agricultural production (especially given the likely pattern of climate change across Australia). For example, many viticultural producers are relocating to Tasmania as they are unable to keep growing key varieties in traditional production areas on the Australian mainland given warming temperatures, changing seasons and increased pest burdens.

State planners have also made significant progress towards legislative changes, i.e., *Market initiating changes – Stage I and II* in Step 2. For example, as each irrigation region is developed, unbundled water entitlements will be sold via an open tender using a reserve price. Moreover, ongoing operational costs, including asset refurbishment or renewal provisions will not be subsidised, and must be met by annual water charges on licence holders (making them consistent with the Australian *National Water Initiative*). Other market reforms include a water register that defines licence ownership, protects registered financial interests and facilitates both temporary and permanent transfers. An online trading platform has also been established to reduce trade transaction costs; although an identified institutional weakness is that the TI register does not have the capacity or the legal obligation to record price data (NWC, 2013a).

The application of the WMRA framework (Table 3) to Tasmania indicates that many prerequisites for effective and efficient trade are present. For example, there is a cap on resources; a water plan and rigorous planning process; robust entitlement registers and water accounting arrangements with all barriers to trade (other than those hydrologically justified) removed. In addition, there are no restrictions on ownership and no requirements to use all allocated water, and any unintended trade-related environmental externalities are adequately managed by regulation.

TI has therefore reached Step 3 of the framework: *Trade enabling mechanisms*, where change and adaption is needed as a result of future monitoring and assessment. Further development of trade between users and monitoring of progress will help determine future changes or reforms. As a consequence, there may be a need for further adjustments to the steps of *Existing institutional, planning and property right arrangements* and *Market initiating changes – Stage II*, such as improved data collection and other water planning arrangements needed to sustain market development.

5.4. Summary and discussion of key insights from the regional examples

Table 3 provides the overall summary, and the application of the framework to our specific regional examples. Apart from the key fundamental need for strong, trusted institutions and governance to allow the development of water markets in any jurisdiction, which limits the regions where water trade can be successfully applied, there are three important lessons that emerge from the application of the WMRA framework to the examples: i) unbundling; ii) sequencing; and iii) 'never waste a good crisis'.

In many jurisdictions unique bundling arrangements are used to protect the resource by keeping use within sustainable limits. A water licence may, for example, require that the water be used only for a specific purpose and applied in a specific manner. Such arrangements discourage conservation and make it difficult for administrators to reduce total use. In Spain, the continued existence of uncertain property right enforcement limits for trading outside a communal area, is an important barrier to efficient water-use and discourages investment—which is avoided in the MDB given the fact that entitlements are issued to users rather than the community and local controls on the trade of shares and/or annual allocations confined to the setting of reasonable exit fees. The costs of trading shares and allocations are low and can be finalised quickly. This avoids any obligation to use all annually allocated water and incentivises investment in water conservation; especially when it is possible to save water for subsequent use as will soon be the case in the Diamond Valley. The Tasmanian example highlights the value (and necessity) of unbundling water rights ahead of introducing trade arrangements. These arrangements encourage the management of long-term supply risk with water via water entitlement trade, while water allocation trades encourage efficient water-use on a day-by-day basis.

As identified by Young (2014b), correct sequencing of water reforms is critical. A recognition of the limits to water-use, associated restrictions on further extraction and genuine incentives to change behaviour are all essential factors in successful water market adoption. In particular, rights and water accounting rules need to be consistent with hydrological realities. Return flows, for example, should be included in the water markets accounting framework. In the Spanish example, although return flows are often accounted for within an irrigation community, conflicting allocation requirements and hydrological information about environmental flows place the GRB at high risk of desertification due to water over-extraction. Thus, Hernández-Mora and del Moral (2015) argued that a great deal of further institutional development was required before water trade can be increased. This highlights that implementing water trading without fully implementing the required laws, institutional capacity and administrative systems in a basin will only increase transaction costs; and fuel scepticism about market benefits.

Each of the applied examples provide key lessons about the opportunities that can be garnered from crises and using trade as a means to keep water-use within limits. Arguably, real gains come from the fact that trading encourages the development of administrative systems that are self-enforcing. In Tasmania, the consequences of costly climate change on traditional agricultural production (especially viticulture), the success of MDB water markets (and the ability to consider the lessons from earlier mainland water market establishment) enabled planners to select the most suitable institutional reforms and systems needed. By contrast, in the Diamond Valley the water crisis has resulted in the willingness to implement considerable institutional and property right change and funding to rectify key hydrological information gaps.

Our application of the WMRA framework to the examples in this study indicates that it provides a useful tool for helping water planners/managers to evaluate the relevant information/conditions needed for water markets and, as a consequence, potentially respond to the fundamental problems of water scarcity. The application of the framework suggested it may serve as a practical, relatively quick and non-prescriptive means for water managers/policy makers in different jurisdictions to assess the appropriateness of emergent or developing water market arrangements.

We stress that the development of successful market reforms depends critically on the existence, impartiality (and security) of local water institutions. Our applied examples provide evidence of how jurisdictions undertake their planning process and how, during the development of water allocation plans, those with existing rights to water are required to engage as part of extensive stakeholder consultation. Where stakeholder consultation occurs, this may ensure that knowledge held by these groups is not overlooked, reduce community and political opposition, and potentially lower the cost of (further) modifying extraction or consumption limits. Further, where a resource is shown to be over-extracted/consumed and new information arises about the unsustainable nature of extractions, reductions in use can then be managed in a manner that does not necessarily negatively impact market confidence. This is encapsulated in our WMRA framework. Nevertheless, we acknowledge that this framework is only a first step forward; further testing, application and refinement will obviously be required. Further research would help operationalise WMRA as would consideration of comparable measures within and across examples/scales and over time, particularly in regards to trading activity.

6. Conclusion

Water demand-management strategies will need to be implemented across the world as regions increasingly grapple with water scarcity. One possible strategy includes the establishment of water entitlement and allocation systems that make rapid, low-cost water trading possible. The applicability of such systems to various regions is often unknown, and there is a dearth of information, guides or manuals that show water managers and planners how to proceed. To assist this process, a WMRA framework (and associated set of questions) was developed to offer practitioners a non-prescriptive three-step framework: 1) assess hydrological and institutional needs; 2) evaluate market, development and implementation factors; and then 3) monitor and continuously assess effectiveness.

The framework was applied to three examples from different countries to help evaluate the potential for water markets to address water scarcity issues, by an assessment of market enabling/constraining conditions. Our preliminary findings suggest that WMRA may help practitioners identify the reforms needed to help improve existing arrangements, or correspondingly identify that market arrangements are not possible for their region. As with any proposed framework, further testing and application is required to assess its applicability and value.

Acknowledgements

None of the authors' affiliations or employment positions provides any conflicts of interest that must be raised. This work was supported by the Australian Research Council [FF140100733, DE150100328 and DP140103946], and the Australian National Commission for UNESCO. The authors gratefully acknowledge the Australian *National Water Commission's* role in originally driving this research, and for allowing the authors to access material under its care. We are also indebted to helpful comments received from reviewers and to Sara Palomo-Hierro for her help with Spanish water market literature.

Appendix A: Water market assessment questions

Issues	Questions to guide discussion/thinking	Priority
Property Rights/Institutions		
Legislation	Does legislation exist which gives a clear understanding of rights to water for individuals/corporations and other legal entities? If so, is the degree of attenuation clear, and which legislation (or pieces of legislation) are pertinent?	*****
	Are the rights separable – or attached to other rights such as land?	****
Individuals/groups	Do the rights vary for classes of right holders and or with respect to time (for example, rights that may have been established under different law in time)?	*
Environment	If so, what are the differences in the classes of rights?	*
Change/adaptation mechanisms	Are rights transferrable, and is there a legislative mechanism for enabling transfer?	*****
Road to other property rights	Can permanent and temporary trades take place – what is the impact of permanent trades on viability of infrastructure services along parts of the system network?	***
Unbundled rights	Is trade only provided for in relation to entitlements, or can trade in derivatives take place?	**
Risk assignment	Can a trade be readily enforced and/or reversed if counterparty defaults?	**
	How are property rights enforced, and is the enforcement regime effective and efficient?	****

(*continued on next page*)

Appendix A: Water market assessment questions (*continued*)

Issues	Questions to guide discussion/thinking	Priority
	What are the rules, if any, relating to carryover and other future period transfer of unused portion of allocations in any year?	*
	What rules/constraints attach to trading rights between connected systems?	****
	What rules attach to the technology underpinning the delivery of water to users – such as season delivery rules, channel delivery rules, etc.?	****
	Are the rights able to be qualified in any other way – and if so, on what basis?	**
	What is the risk attached to the characteristics of rights – and when does the risk materialize and can the risk be transferred with the right?	**
	How are rights presently allocated/weighed between uses – such as urban water corporations and the environment, and what interplay is there with the rights that are privately held?	*
	How do others (e.g. financial institutions/property valuers) view the value and risk profile of rights?	**

Hydrology		
Connected systems	Is the hydrology of the system well understood, well documented, and monitored and reported on in a way that is supportive of trade?	*****
Regulated/Unregulated	Is there groundwater interaction with surface-water and are the interactions understood, documented, monitored and reported on?	*****
Limit & consequences of breach → environment → end of system	Are the systems modelled and is the impact of a range of future resource scenarios understood by potential market participants and regulators in relation to the system performance (both in terms of economic and environmental use)?	****
Use, including interception	Is interception of run-off included in the measurement and management of the system – or is there risk to catchments from growth in 'off stream' interception?	***
Do we know what we don't know	Have water quality and or environmental considerations the potential to cause the system to fail?	***
Salinity/water quality considerations	Is the interoperability that results from trade tested or modelled?	*****
	Big picture assessment to bring these two areas together – are the rights articulated in a way that is sympathetic to:	***
	• The resource constraint; and	******
	• The extent to which resource knowledge is complete.	
Externalities & Governance Considerations		
Institutional Governance	Is the administrative culture and behaviour of those involved in making decisions respected and trusted? In other words, is the governance of an area strongly impartial?	****
Sleeper/dozers	Are there rights in existence that have been inactive, that if traded into a market, may over commit the resource?	***
Input on average vs 70% rule	How does change of use impact on external environment – energy and road infrastructure, supply chains, demand for labour, etc.? And is this a pecuniary externality or a real externality (noting only the latter should be a policy concern)	**
Known change of use and hydrology inputs	Does the supplier have the systems, resources and technology to monitor use, and to ensure use is within licences/entitlements?	****
Unregulated "use"	Can unregulated use be detected?	***
Metering/Compliance	Can water use be metered, enforced, with penalties imposed?	****
Adjustment		
Heterogeneity → Gains from trade	Is there a sufficiently diverse (potential) market for water use in the system to facilitate trade (willing buyers/sellers with different use profiles in terms of value add per $ of water) and what is the likely magnitude of these gains (ex-transaction costs)?	*****
Societal pressures	Is the political context mature enough to deal with trade – and accepting of the gains from trade as well as the adjustment costs in terms of activity changes that will be involved with trade?	*****
New knowledge	Is there access to the skills, knowledge and finance needed to take advantage of the production possibilities afforded by access to water from trade?	*
Early-mover advantage		

Entitlement registers and accounting systems		
Legislation	Has the State made plans for trade in the system, and how far advanced is the planning?	****
Plans	Are enabling resources (e.g. registers) available/reliable/ trustworthy?	*****
Registers	Is information made available on likely market conditions for trade, and is it reliable and trustworthy?	****
Early-mover legislation	How mature, effective and efficient are the regulatory settings, the institutions and the services that support trades (e.g. Online trading platforms).	****
Information availability	Have intermediaries indicated a willingness to support the function of the market?	***
Allocation announcements		
Compliance		
Monitoring, Evaluation and Review		
Intermediaries		
System Type		
Regulated/unregulated	Which water sources in the system are capable of being made available for trade?	****
Surface-water/Groundwater	What is the status of infrastructure and what are the costs of accessing water in the system, and at various parts of the system?	*****
Connectivity	Does trade need to be regulated for system performance and/or economic and social interests in different parts of the system and at whose cost (benefit)?	***
	If so – have the rules for trade been identified based on reliable data and articulated to the market and regulators?	***

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