STUDY ON THE LEGISLATIVE FRAMEWORK REGULATING THE RECHARGE OF AQUIFERS WITH ADEQUATELY TREATED WASTEWATER

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The SWIM Program (2010 – 2014)

Contributing to Sustainable Water Integrated Management in the Mediterranean

Funded by the European Commission with a total budget of approximately € 22 million, Sustainable Water Integrated Management (SWIM) is a Regional Technical Assistance Program aiming to contribute to the effective implementation and extensive dissemination of sustainable water management policies and practices in the South-Eastern Mediterranean Region in view of increasing water scarcity, combined pressures on water resources from a wide range of users, desertification processes and in connection with climate change.

The SWIM Partner Countries (PCs) are: Algeria, Egypt, Israel, Jordan, Lebanon, Libya[1], Morocco, Palestine, Syria and Tunisia.

SWIM aligns with the outcomes of the Euro-Mediterranean Ministerial Conferences on Environment (Cairo, 2006) and Water (Dead Sea, 2008) and also reflects on the four major themes of the draft Strategy for Water in the Mediterranean (SWM), mandated by the Union for the Mediterranean, namely: Water Governance; Water and Climate Change; Water Financing and; Water Demand Management and Efficiency, with particular focus on non-conventional water resources. Moreover, it is operationally linked to the objectives of the Mediterranean Component of the EU Water Initiative (MED EUWI) and complements the EC-financed Horizon 2020 Initiative to De-Pollute the Mediterranean Sea (Horizon 2020). Furthermore, SWIM links to other related regional processes, such as the Mediterranean Strategy for Sustainable Development (MSSD) and the Arab Water Strategy elaborated respectively in the framework of the Barcelona Convention and of the League of Arab States, and to on-going pertinent programs, e.g. the UNEP/MAP GEF Strategic Partnership for the Mediterranean Large Marine Ecosystem (Med-Partnership) and the World Bank GEF Sustainable Mediterranean.

The Program consists of two Components, acting as a mutually strengthening unit that supports much needed reforms and new creative approaches in relation to water management in the Mediterranean region, aiming at their wide diffusion and replication.

The two SWIM Components are:

- A Support Mechanism (SWIM-SM) funded with a budget of € 6.7 million and
- Five (5) Demonstration Projects funded with a budget of approximately € 15 million

For more information please visit http://www.swim-sm.eu/or contactinfo@swim-sm.eu

[1]The situation in spring 2012 is that following formal EC decision, activities have been stalled in Syria while Libya has officially become a Partner Country of the SWIM Program

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List of Acronyms

ADWR	Arizona Department of Water Resources
AHMC	Australian Health Ministers' Conference
AR	Artificial Recharge
ASR	Aquifer Storage and Recovery
ASTR	Aquifer Storage, Transfer and Recovery
DoW	Department of Water (Western Australia, Australia)
DSE	Department of Sustainability and Environment (Victoria, Australia)
DWAF	Department of Water Affairs and Forestry (Republic of South Africa)
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency (USA and Victoria, Australia)
EPHC	Environment Protection and Heritage Council (Australia)
EU	European Union
IWRM	Integrated Water Resources Management
NNC-IAH	Netherlands National Committee for the International Association of Hydrogeologists
NRMMC	Natural Resource Ministerial Management Council (Australia)
NHMRC	National Health and Medical Research Council (Australia)
RMP	Risk Management Plan
SAT	Soil Aquifer Treatment
SWIM-SM	Sustainable Water Integrated Management – Support Mechanism project
TWW	Treated Waste Water
UAR	Unmanaged Aquifer Recharge
WHO	World Health Organization

Executive Summary

The potential for indirect reuse of adequately treated wastewater via aquifer recharge for potable and/or irrigation and/or environment support supplies is significant. Managed aquifer recharge (MAR), also known as enhanced recharge, water banking and sustainable underground storage, is the purposeful recharge of water to aquifers for subsequent recovery or environmental benefit. MAR is in wide use in many countries to enhance water supplies, however uptake has been constrained by lack of a policy and a clear and consistent regulatory framework that allows the benefits of MAR to be materialized. This report seeks to bridge the regulatory gap by providing guidelines for a regulatory framework for MAR schemes which use adequately treated wastewater as source water. It builds upon the available literature, and on original case studies illustrative of regulatory approaches and experience in five selected countries.

The case studies show that no country has yet adopted a specific set of provisions on MAR, rather regulating the different stages of MAR-related activities through existing legislation on groundwater abstraction, wastewater discharge and treated wastewater reuse. Land use planning and environmental impact assessment legislation add to the complexity of the regulatory frameworks currently available for MAR schemes. Against this backdrop, the guidelines seek to bring about integration via **integrated MAR licensing.** This covers the four operational elements of MAR schemes using treated wastewater (TWW) as source water, i.e., source water harvesting, aquifer storage and recharge, the recovery of stored water and final use of recovered water. The guidelines address the exclusive rights and obligations to own, access, manage, recharge, extract and use MAR source water (TWW), aquifer storage and recharge space, and recovered water. They further address the quality of TWW, of groundwater in the aquifer which is recharged, and that of recovered water, for the protection of human health and the environment.

The scope and features of the integrated MAR licensing system are illustrated by reference to a number of discrete **constituent elements of a future MAR-specific regulation**, part of which fleshes out and qualifies the rights to harvest source water (TWW), to store and recharge TWW to an aquifer, to recover recharged water from an aquifer, and to use recovered water. The necessary links are secured with requirements mandated by land use planning and by environmental impact assessment legislation. These aspects are bundled up and dealt with as Theme I. Another part of the MAR-specific licensing and regulation covers the protection of human health and the environment, with prevention of hazardous events from occurring being the central philosophy and approach, and with the identification, assessment and mitigation of relevant risk being at the core of prevention. This is accomplished through the instrument of a risk management plan, whose features are sketched out (Theme II). Some cross-cutting MAR licensing issues, i.e., the review, variation, suspension and termination of a MAR license, are dealt with and grouped as Theme III. Administration, monitoring and enforcement are also touched upon as Theme IV, with the government water resources authorities seeming to be the best placed to undertake the lead role, with the concurrence of the health and the environment protection authorities.

The report and the Guidelines **are recommended** to the attention of SWIM Partner Countries as a source of inspiration and guidance in devising a policy and a regulatory framework facilitating the development of TWW-sourced MAR. Review and fine-tuning of the Guidelines **are recommended** as SWIM Partner Countries develop their own regulatory framework based on their national specificities, and as the Guidelines are put to the test.

1 Introduction

BACKGROUND AND CONTEXT

The overall objective of the SWIM-Support Mechanism (SM) program component is to promote the extensive dissemination of sustainable water management policies and practices in the region in the context of increasing water scarcity, combined pressure on water resources from a wide range of users and desertification processes, in connection with climate change. The specific objectives of the SWIM-SM are to: (1) raise the awareness of decision-makers and stakeholders in the Partner Countries on existing and upcoming threats to water resources, on the necessity to switch to more viable water consumption models as well as on possible solutions to face the challenges; (2) to support the Partner Countries in designing and implementing sustainable water management policies at the national and local levels, in liaison with on-going relevant international initiatives; and (3) to contribute to institutional strengthening, to the development of the necessary planning and management skills and to the transfer of know-how.

Within such a context, SWIM-SM is addressing non-conventional water resources as a promising option to partially fill the gap and provide better balance between water supply and demand in the region. Groundwater aquifer recharge using adequately treated wastewater is gaining momentum as a valid option to ease the pressure on groundwater over-exploitation and in many cases to reduce saline water intrusion. The interest of SWIM Partner Countries in applying artificial recharge of groundwater has been stifled by weak institutional arrangements, inadequate wastewater treatment, ineffective environmental management, and **the near absence of regulations, guidelines and operational criteria for this practice**. It is with a view to bridging this last gap in particular that SWIM-SM is undertaking the current activity, with the aim of developing a regulatory framework for the use of adequately treated wastewater in the artificial recharge of aquifers, including the development of guidelines and a review of good practices.

ABOUT MANAGED AQUIFER RECHARGE (MAR)

The potential for indirect reuse of treated wastewater (also known as reclaimed water or recycled water), via aquifer recharge for potable and/or irrigation supplies is significant. The relevant technique, known as "**soil aquifer treatment" (SAT)**, is one of several techniques which fall under the **"management of aquifer recharge", or "managed aquifer recharge" (MAR).** Through SAT, reclaimed water is intermittently infiltrated through infiltration ponds to facilitate nutrient and pathogen removal in passage through the unsaturated zone for recovery by wells after residence in the aquifer. Other techniques of relevance in this context are: **aquifer storage and recovery (ASR)**, consisting of the injection of treated wastewater into a well for storage and recovery from the same well; and **aquifer storage, transfer and recovery (ASTR)**, whereby treated wastewater injected into a well for storage is recovered from a different well, generally to provide additional water treatment.

Box 1: **MANAGED AQUIFER RECHARGE**

An aquifer is an underground reservoir of water contained by rock or unconsolidated materials (gravel, sand, silt or clay), from which groundwater can be extracted. In 'managed aquifer recharge' a water source, such as recycled water (e.g. derived from urban storm water or treated sewage) or natural water (e.g. from a lake or river), is used to 'recharge' an aquifer with water under controlled conditions. The aquifer is used to store surplus water for later use or for environmental benefit.

(**Source:** NRMMC–EPHC–NHMRC, 2009, *Australian Guidelines for Water Recycling – Managed Aquifer Recharge*, p1)

MAR is the purposeful recharge of water to aquifers for subsequent recovery or environmental benefit. It is not a method for waste disposal although, in actual practice, MAR tends to be regulated partly by wastewater discharge/water pollution control legislation. MAR is therefore intentional, as opposed to the effects of land clearing, irrigation, and installing water mains where recharge increases are incidental. **MAR is also known as enhanced recharge, water banking and sustainable underground storage**.

MAR may play an important role as part of a package of measures to control abstraction and restore the groundwater balance. It can be used to enhance base flow in streams that support aquatic ecosystems and downstream water supplies, in addition to protecting aquifers from seawater intrusion, salinization or land subsidence, and to sustaining groundwater-supported local livelihoods, economic activity in general, and ecosystems. With appropriate pre-treatment before recharge and sometimes post-treatment of recovered groundwater, it may be used for drinking water supplies, industrial water, irrigation, toilet flushing, and sustaining ecosystems.

MAR is in wide use in many countries to enhance water supplies, particularly those in semi- arid and arid areas, but also in humid areas, primarily for water quality improvement. Technologies have been developed to produce safe and reliable water supplies out of recovered water. However **uptake has in many cases been limited by lack of a policy and a clear and consistent regulatory framework** that allows the benefits of MAR to be materialized.

SCOPE, STRUCTURE AND PURPOSE OF REPORT

This report sketches out a regulatory framework for MAR schemes which use treated wastewater as source water. It builds upon the available literature[2], and upon five original case studies focussing on the regulatory dimension of MAR, with a particular view to the use of adequately treated wastewater as source water, referred to in this report as **Treated Waste Water (TWW)**. The five case studies illustrate the regulatory approach and experience in **South Africa, Israel, the State of Arizona (USA), the State of Western Australia (Australia), and Spain**. Guidelines for a regulatory framework for MAR schemes using TWW as source water, which are partly based on the case studies, are at the core of this report and exercise. Conclusions are finally drawn, and recommendations offered for consideration by the SWIM Partner Countries based, in particular, on the Guidelines.

To this effect, **this report, and the guidelines in particular, are intended to assist legislators and government officials in the design and administration of a regulatory environment for the safe "managed aquifer recharge" with adequately treated wastewater**.

[2]The principal source of inspiration for these Guidelines are the Guidelines for Managed Aquifer Recharge (MAR) issued by the National Water Commission of Australia, as Waterlines Report Series No.13, February 2009 and No.38, January 2011 (see the List of References).

2 Brief Overview and Analysis of Good Practices & Success Stories in Developing and Administrating Regulatory Systems for the Artificial Recharge of Aquifers with Treated Wastewater

2.1 South Africa

Under the general framework of the **National Water Policy for South Africa** and the **National Water Resources Strategy**, an **Artificial Recharge Strategy** was finalised in 2007[3]. "Artificial recharge (AR) is [defined as] the process whereby surface water is transferred underground to be stored in an aquifer" (p. 2). One of the management objectives of the strategy (legislation and regulation) is to "enable water management and water services institutions to adopt and regulate artificial recharge as part of Integrated Water Resources Management (IWRM)" (p. 119). South Africa has longstanding experience in artificial groundwater recharge. The city of Atlantis started recharging its aquifer with storm water and treated wastewater in 1979. At that time, the 1956 Water Act (No. 54 of 1956) was still in force, and artificial recharge and water recycling were not regulated under its provisions (DWAF, 2010).

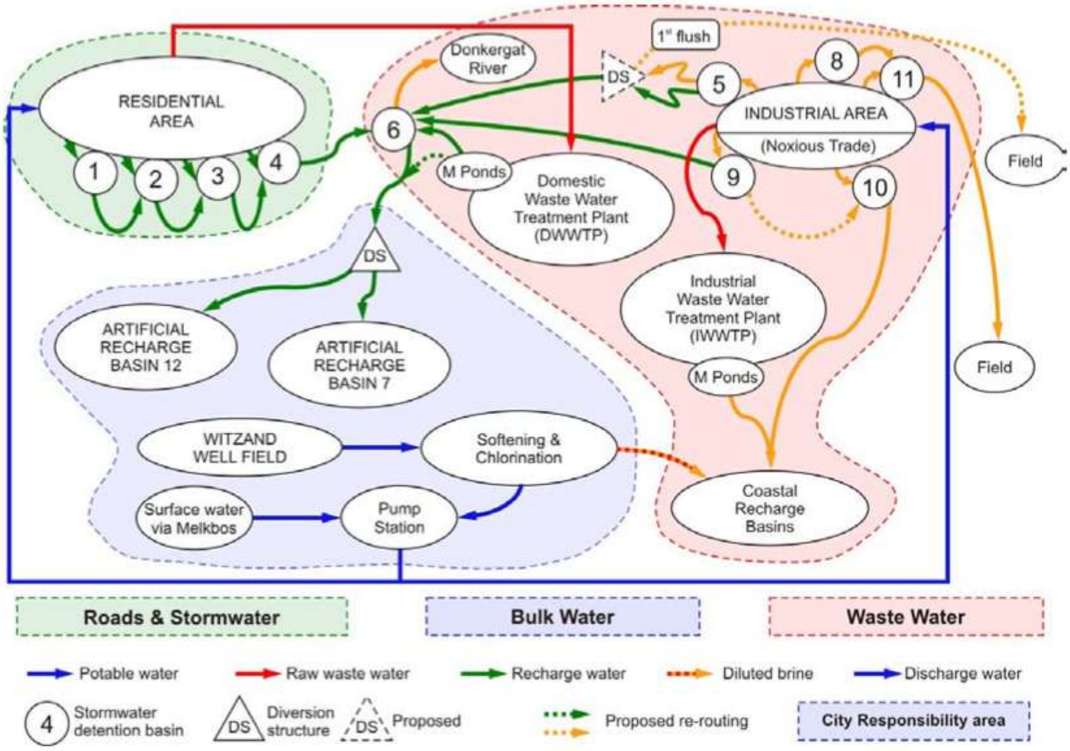

Figure 1: Overview of the Witzand facilities within the Atlantis Water Resources Management Scheme

Although there is still no consistent legal framework for AR, the current **Atlantis Water Resources Management Scheme** (Figure 1) has to comply with the **National Water Act (NWA)** – No. 36 of 1998 – which explicitly regulates artificial groundwater recharge with treated or untreated wastewater. The Act arguably requires a licence for artificial groundwater recharge regardless of the source water when it identifies "storage of water" (art. 21(b)) among the 11 regulated water uses. Although at the time of drafting "storage of water" was intended for dams and canals[4], artificial groundwater recharge schemes

[3] Artificial Recharge Strategy, Version 1.3, June 2007, DWAF.

[4] "The license application form pertaining to storage describes the storage of water in dams and is inadequate to describe the storage of water in an aquifer" (DWAF, 2007).

may certainly be licensed under this use considering that the primary purpose of aquifers recharge is undoubtedly water storage (DWAF, 2007)[5].

In addition, the Act requires a special authorization for "controlled activities", which include the "intentional recharging of an aquifer with any waste or water containing waste" (art. 21(e) and 37, NWA). The **External Guidelines – Generic Water Use Authorisation Application Process** of the **Department of Water Affairs (DWA)** state that, "if the proposed water uses comprise an integrated water use licence application, which combines both non-waste discharge and waste discharge-related water uses in a single application then a risk assessment must be undertaken for all the uses."[6]

According to the 2007 AR Strategy, the procedure for the implementation of an artificial recharge project includes four stages, namely a *pre-feasibility stage*, a *feasibility or testing stage*, an *implementation stage*, and an *operation, monitoring and maintenance stage*. In order to identify suitable areas for artificial recharge, the checklist adopted for the first two stages includes 10 success criteria assessing: 1) demand (the need for an artificial recharge scheme); 2) supply (source water); 3) aquifer characteristics (aquifer hydraulics); 4) water quality; 5) applicable method (engineering issues); 6) environmental issues; 7) legal and regulatory issues; 8) economics; 9) technical capacity (management); and 10) institutional arrangements (Murray, 2009, as cited in Steinel, 2012, p. 43).

The *pre-feasibility report* is submitted to DWA, jointly with the licence application for testing, if required. DWA may convene an **Artificial Recharge Authorities Committee Meeting**, with other competent authorities, including Department of Environmental Affairs and Tourism and the relevant Catchment Management Agencies. If an environmental authorisation is required for testing under the **Environmental Impact Assessment (EIA) Regulations** (2010) (Government Notice No. 543 in Government Gazette No. 33306 of 18 June 2010), a **Basic Assessment Report** or a **Scoping and Environmental Impact Report (S&EIR)** should be added to the pre-feasibility file. At the second stage, testing is carried out upon authorisation, if required. The *feasibility report* is submitted to DWA, jointly with the licence application for the desired water use and the environmental authorisation, if required. At the third stage, *implementation of the project* may commence upon issuance of the licence. The fourth stage – *operation and maintenance, or production* – should include performance monitoring.

In South Africa, the main water authority is the Ministry of Water Affairs. The Minister is the custodian of water resources and has the ultimate responsibility to ensure that water is protected and allocated in the public interest. The DWA – formerly Department of Water Affairs and Forestry (DWAF) – is delegated by the Minister to administer the NWA. Its mandate focuses on developing the national water policy and water management regulations, and on supervising water-related activities of other institutions, including water users' associations. All water resource management institutions must function in accordance with the National Water Resource Strategy.

Catchment Management Agencies (CMAs) are being established in each of the 19 water management areas. DWA may delegate water licensing to the CMAs. The **Department of Environmental Affairs and Tourism (DEAT)** is involved in water management where an environmental authorisation is required,

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[5] According to the Act, all water uses are subject to a licence, except those identified as permissible by the Act or in terms of a "general authorisation" (art. 22, NWA). The Minister may issue general authorisations for certain water uses, the effect of which is to exempt users falling under the relevant category from requiring a licence. However, the "storage of water underground" is explicitly excluded from the scope of the general authorisation for water abstraction and storage (Government Notice No. 1199 of 1999). This implies that underground water storage requires a licence.

[6] According to the author, unless new standards have been adopted under the 1998 NWA, the wastewater standards set under the 1956 Water Act by Regulation No. 991 of 1984 – Requirements for the purification of waste water or effluent (Government Gazette No. 9225 of 18 May 1984) – are still in force.

under the **National Environmental Management Act** (No. 107 of 1998) and the **Environment Conservation Act** (No. 73 of 1989). Water Services Authorities and Water Services Providers, including Water Boards, are in charge of drinking water supply under the **Water Services Act** (No. 108 of 1997).

The **Waste Management Policy** includes the **Policy and Strategy for Groundwater Quality Management in South Africa** (2000), according to which "National Government, acting through the Minister, is the public trustee of the country's water resources. Surface and groundwater quality management are both important parts of his responsibility". Among the functional strategies provided for, sewage treatment is a priority to be addressed through regulations, standards and guidelines. Aquifer management strategies regarding groundwater quality are only required "for large and continuous aquifers", whereas "localised and poorly defined aquifers" are generally part of a catchment management strategy (Groundwater Quality Policy, 2000).

2.2 Israel

Israel has been practising wastewater treatment and reuse since the '50s and '70s, including through groundwater recharge (**Soil Aquifer Treatment – SAT**) (Tal, 2013). **The country has a 75% water reuse rate** [Spain 12%; Australia 9%] (Mekorot, 2013). Artificial groundwater recharge serves a number of purposes in Israel, namely increasing water reserves for periods of high demand (primarily for irrigation), reducing hydrological deficits, preventing saline intrusion from peripheral areas and ensuring efficient utilisation of surplus water from Lake Kinneret (i.e. Lake Tiberias) (see Israel case study in DWAF, 2007).

Comprehensive water quality monitoring is normally carried out throughout all the stages of the recharge process. However, besides known problems related to clogging of recharge boreholes due to silt build-up and algae in the source water (Mekorot, 2013), health concerns have been raised lately, as endocrine disruptors, antibiotics and trace metals have been found in recycled water. In order to protect human health and groundwater quality, some experts are now calling for treatment to drinking water quality standards through desalination of treated sewage effluent by reverse osmosis (Tal, 2013).

The largest SAT facility in Israel is the Dan Region Wastewater Treatment Plant (Shafdan), where sewage water from the Tel Aviv region is treated. Wastewater treatment comprises four stages: pre-treatment, primary, secondary and tertiary treatment. Treatment methods include oxidation ponds, activated sludge and Mechanical Bio-Reactor (MBR**)**. The Shafdan effluents are discharged into the soil for tertiary treatment and to recharge the aquifer. Water is then recovered and transported to the Negev for irrigation. The total effluent supplied for agricultural purposes is 216 million cubic meters per year (Mekorot, 2013).

The **Israeli Water Law** (No. 5719 of 1959)[7] states that national water resources (including drainage and sewage water) are the property of the public. They are controlled by the State and are intended to fulfil the needs of the population and the development of the country (section 1). With a view to preventing water pollution in water facilities, the law establishes that anyone who has in his possession a facility for water production, supply, transport, storage or **recharge to the subsoil** must undertake every reasonable measure in order to prevent the facility or its operation from causing water pollution (s. 20C). In addition, anyone who is operating a polluting facility, which requires the disposal of sewage, must submit a sewage disposal plan to be approved by the Director of the **National Authority for Water and Sewage** (s. 20E).

National legislation regulating the use of wastewater for the specific purpose of artificially recharging aquifers includes the following (personal communication to the author):

[7] Unofficial translation from the website of the Israeli Ministry of Environmental Protection (http://www.sviva.gov.il).

a) **National Plan No. 34 B/4 for Collecting Surface Water, Insertion, Recharge, and Protection of Groundwater**. Part C of the plan identifies proposed recharge areas and areas meant for recharge projects. A **building permit** is required for any recharge project in an identified area. The permit will be issued with a detailed implementation plan, in accordance with the National Plan (s. 12). The detailed plan for a recharge site will include the area for spreading and recharge, pipes and equipment for water conveyance and service roads and access. It will also include the facilities for catching and diverting water, reservoirs, equipment for water conveyance including pumps, pipes, canals, dams, etc., and facilities for extraction of the recharge (s. 13). Given the fact that ponds and infiltration basins may attract birds (Atlantis, South Africa (2014 © A.D'Andrea)

), the plan must include measures to ensure flight safety over recharge areas in order to avoid bird strikes. The National Plan specifically includes the Shafdan sewage recharge facility in its scope of application (s. 15).

b) **Public Health Regulations (Regulations for Sewage Quality and Rules for Treating Sewage), 2010, or "Sewage Regulations"**. Recycled sewage water that is used for recharge is mostly intended for irrigation purposes; hence the quality must meet the relevant specifications. **Treatment plants** are divided into "large" and "small" and, within each of these categories, quality values are established according to usage – unlimited agricultural usage, limited agricultural usage and release into streams (s. 4, appendix 1-3). The Sewage Regulations require permits for each usage/disposal method – irrigation, discharge into streams or other economic usage (s. 9). A plan for the control and monitoring of sewage quality is also required (s. 10).

c) **Public Health Rules (Treating effluent for reuse in irrigation), 1981.Yearly permits** are required from the regional engineer of the Ministry of Health for wastewater treatment systems intended for irrigation. **Treated effluents** may only be used for irrigating crops listed in the Public Health Rules[8] and under specific conditions[9], unless it has been treated to the level of "unlimited irrigation" purposes under the 2010 Public Health Regulations. In this latter case, treated water may be used for any type of crops. Farmers irrigating with treated effluents must apply for a permit and respect its terms and conditions. If a crop is not listed in the appendix to the Public Health Rules, a written permission of the Director General of the Ministry of Health is required for irrigation with treated effluents. For example, on 6 October 2013, 60 dunums (15 acres) of zucchini squash were destroyed in the central region, upon order of the local health authority. The order stated that the field was irrigated with effluents that did not meet the quality standards for this type of crop, and without a permit from the Ministry of Health.

[8] The listed crops are: 1. crops that are not used for human consumption, like cotton, seed-growing, and dry fodder; 2. crops meant for industry, that undergo industrial processing that prevents micro-organisms, like cereals and beet sugar, except for crops meant for the canning industry; and 3. forests and groves in places not meant for camping or picnicking.

[9] The conditions are that: 1. the user of the treated effluent has a valid permit and follows all of its conditions; 2. the concentration of dissolved oxygen in the treated effluent is at least half a milligram per litre; and 3. the treated effluent does not contain any toxic compounds that may endanger the health of those coming in contact with the treated effluent or the crops irrigated, whether in the field or after the harvest.

Atlantis, South Africa (2014 © A.D'Andrea)

Figure 2: Different views of an artificial recharge basin in the Atlantis Water Resources Management Scheme

The above-described framework establishes **a web of interlocking regulatory requirements**. The National Plan No. 34 B/4 regulates recharge projects and all aspects thereof, except the quality required of the wastewater being employed for recharge purposes, which is regulated by the 2010 Public Health Regulations. Treatment requirements vary depending on the intended end-use of the recharged aquifer water. The yearly (operating) permit requirements of the 1981 Public Health Rules with respect to wastewater treatment plants intended for irrigation use are additional to, and separate or independent from, the permit requirements of the National Plan. In other words, an aquifer recharge project involving the use of wastewater as source water for future irrigation use must secure a building permit under the National Plan, a recycled water use/disposal permit under the 2010 Public Health Regulations, plus a yearly operating permit of the wastewater treatment plant, under the 1981Public Health Rules.

2.3 Arizona (USA)

2.3.1 Applicable federal legislation

In the United States of America (USA), **Aquifer Storage and Recovery** (ASR) was first introduced in New Jersey in 1969 (Ward & Dillon, 2009). From a regulatory viewpoint, allocation of water rights is generally dealt with at the State level, as well as wastewater reuse regulation, although "much of the regulation of effluent quality takes place at the federal level" (Chapman, 2005). States with "well-developed, comprehensive water reclamation and reuse regulations" include Arizona, California, Florida, and Texas, where there is extensive reuse of water (Crook, 1994, as cited in Chapman, 2005)[10]. In Arizona, the MAR permit system is based on a statutory derivative of the prior appropriation doctrine, like in Colorado, New Mexico and Utah, among others. In California, there is a mixed system of the prior appropriation and the correlative rights doctrines. In Florida, the reasonable use doctrine is applied, whereas Texas has a system based on the absolute groundwater ownership doctrine (Wards & Dillon, 2009)[11].

[10] For an overview of the USA experience, see the 2003 Groundwater Law Sourcebook of the Western US, by G. Bryner and E. Purcell. Natural Resources Law Center, University of Colorado, School of Law.

[11] Under the **absolute ownership doctrine**, landowners own what is below and above their land. They are thus allowed to pump as much groundwater as they wish without compensating other landowners overlying the aquifer. The **reasonable use doctrine** was developed in reaction to the ineffectiveness of the absolute ownership doctrine. Under this doctrine, usage of overlying landowners must be reasonable, beneficial, and not wasteful. The **prior appropriation doctrine** gives priority to those who first use the water supply, thus applying the principle

At federal level, the 1972 **Clean Water Act** (33 USC §§ 1251-1387[12]), which is the main text on water pollution control, and the 1976 **Resource Conservation and Recovery Act**, which is the main federal law governing the disposal of solid waste and hazardous waste, only make provision for the protection of groundwater quality. They do not explicitly provide on artificial recharge of aquifers. Groundwater quality in relation to artificial recharge is regulated under federal drinking-water legislation. Under the 1974 **Safe Drinking Water Act**, the **US Environmental Protection Agency (EPA)** implements the **Underground Injection Control (UIC) Program** (42 USC §§ 300h-300h8 [13]). The Act authorizes EPA to regulate injection wells in order to protect underground sources of drinking water, but an amendment introduced by the2005 **Energy Policy Act** has excluded hydraulic fracturing[14] from EPA's UIC Program (42 USC § 300h d) 1) B) ii) Underground injection defined) and has simplified federal requirements for State programmes involving this technique (42 USC § 300h-4 Optional demonstration by States relating to oil or natural gas).

2.3.2 Arizona State legislation

Arizona's aquifer management legislation is based on two main laws: the 1980 **Groundwater Management Act** (Arizona Revised Statutes – ARS, Title 45 Water, Chapter 2 Groundwater Code) and the 1994 **Underground Water Storage, Savings, and Replenishment (UWS) Act** (ARS, Title 45 Water, Chapter 3.1 UWS), under which the UWS Program (Storage Program) operates[15]. Somebody wishing to store, save, replenish or recover water through the Storage Program must apply for permits through the **Arizona Department of Water Resources (ADWR)**. Depending on the intended activity, up to three types of permits may be required: a Facility Permit – **Underground Storage Facility (USF)** or **Groundwater Savings Facility (GSF) Permit**[16] – for the operation of the storage facility, a **Water Storage (WS) Permit** to allow the holder to store water and a **Recovery Well (RW) Permit** for the recovery of stored water (or credits, in case of a GSF).

Firstly, USF Permit applicants must prove that legal access or the right to acquire legal access to the site (or to the storage space) has been obtained. Secondly, WS Permit applicants must prove their right to use the source water. In the case of effluents, the 1989 Arizona Supreme Court decision (Arizona Public Service Co. v. Long, 160 Ariz. 429, 773 p. 2d 988, as cited in the **USF and WS Permit Application Guides** of the ADWR) established that the entity generating the effluent (possibly the effluent discharge permit holder) has the right to put it to a beneficial use or convey it to another entity that will put it to a beneficial use. If the applicant did not generate the effluent, the legal right to the effluent must be

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"first in time, first in right". Permits are often required, by statute, in order to establish priority in use. Under the **correlative rights doctrine**, each user has an equal right to use of the groundwater regardless of who the first user was. If water is insufficient, users may be required, by the judiciary or by statute, to reduce their usage on a pro-rata basis until the overuse ends. (Bruggink, 1992, as cited in Ward & Dillon, 2009)

[12] US Code, Title 33 Navigation and Navigable Waters, Chapter 26 Water Pollution Prevention and Control.

[13] US Code, Title 42 The Public Health and Welfare, Chapter 6A Public Health Service, Sub-Chapter XII Safety of Public Water Systems, Part C Protection of Underground Sources of Drinking Water.

[14] Hydraulic fracturing is a controversial technique for the abstraction of oil and gas and the production of geothermal energy based on the injection of high-pressure water underground to break the rock and release the resource. The injected water is typically mixed with propping agents that may pollute aquifers. This exclusion has been called the "Halliburton Loophole", Halliburton being one of the world's largest providers of hydraulic fracturing services (Bloomberg, 2012).

[15] Arizona Storage Program (http://www.azwater.gov/AzDWR/WaterManagement/Recharge/).

[16] A USF permit allows the permit holder to operate a facility that stores water in the aquifer (ARS § 45-811.01). A GSF permit allows the permit holder to deliver a renewable water supply, called *in-lieu* water, to a recipient who agrees to replace groundwater pumping with such water, thus creating a groundwater savings (ARS § 45-812.01). Water credits are operated through the **Arizona Water Banking Authority**.

proven through a contract or agreement with the effluent originator. In view of their contractual nature, the trade of effluents rights is "exempt from general water exchange permitting rules" (Chapman, 2005).

Thirdly, a RW Permit is required to recover water that was stored under a WS Permit. The right to withdraw stored water is linked to qualitative and quantitative variables: recharged water must meet the target quality levels for intended use before being recovered; water must be available at the time of withdrawal, considering pre-existing rights to withdraw water from the aquifer. In this regard, aquifer users in the area may withdraw from the recharged aquifer by accounting for it in the total amount of water allowed in their abstraction permit (Ward & Dillon, 2009). In fact, in most cases, no distinction seems to be possible in practice between existing (or "native") and recharged groundwater.

In addition, water storage projects (both from treated sewage/wastewater effluents and from surface water[17]) require an **Aquifer Protection Permit (APP)** to be issued by the **Arizona Department of Environmental Quality (ADEQ)**, prior to filing the USF Permit application. Moreover, a variety of wastewater treatment regulations and standards have been adopted for recycled water reuse for irrigation, for environmental purposes, for indirect potable use and for direct reuse (Chapman, 2005). These regulations may be applicable to either source water or to recovered water, or both, depending on the final use considered.

2.4 Western Australia (Australia)

2.4.1 Applicable national legislation

At the federal level, the definition of groundwater provided by the 2007 **Water Act** includes water that naturally occurs in aquifers, as well as "water occurring at a place below ground that has been pumped, diverted or released to that place for the purpose of being stored there; but does not include water held in underground tanks, pipes or other works" (art. 4). **Australian Guidelines for Water Recycling** are being prepared under the **National Water Quality Management Strategy** [18]. Among these are the **National MAR Guidelines**, published in 2009 (Document No. 24), which focus "primarily on the protection of aquifers and the quality of the recovered water in managed aquifer recharge projects using all water sources including recycled water".

In Australia, the first successful MAR trials were made in the 1960s (e.g. Queensland) via infiltration basin for irrigation and in the 1980s (e.g. South Australia) via recharge wells. However, the first **Unmanaged Aquifer Recharge (UAR)** experiences go as far back as the 1830s and the 1880s (respectively in Perth and Mount Gambier) where recharge occurred from roof run-off infiltration and drainage wells (Parsons *et al.*, 2012). According to the 2009 MAR Guidelines, UAR is an "intentional water-related activity, known to increase aquifer recharge, but usually undertaken to dispose of water rather than recover it" (p. 21). To date, trials of storm water aquifer recharge and recovery have been made in a number of States, but MAR trials with recycled water have only been carried out in **Western Australia** and **South Australia.**

The implementation of MAR schemes generally falls under State legislation. However **only three States have adopted a MAR policy so far, namely Western Australia, South Australia and Victoria**, but no

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[17] Except where source water comes from the Colorado River through the Central Arizona Project (CAP).

[18] There are four subsets of Australian Guidelines for Water Recycling: 1. Managing Health and Environmental Risks (Natural Resource Ministerial Management Council (NRMMC), Environment Protection and Heritage Council (EPHC), Australian Health Ministers' Conference (AHMC), 2006); 2.Augmentation of Drinking Water Supplies (NRMMC–EPHC–National Health and Medical Research Council (NHMRC), 2008); 3.Stormwater Harvesting and Reuse (in preparation); and 4.Managed Aquifer Recharge, NRMMC–EPHC–NHMRC, 2009.

MAR trials with recycled water have been made in the last State so far. Following the Western Australia case below, a brief review of the MAR framework in the other two States is reported.

2.4.2 Western Australia State legislation

In Western Australia, the **Department of Water (DoW)** has issued an **Operational Policy 1.01 – Managed Aquifer Recharge in Western Australia** (DoW, 2011) that describes the procedures for the operation of a MAR scheme. Under the 1914 **Rights in Water and Irrigation (RWI) Act**, water that is infiltrated or injected into the natural groundwater system is vested in the Crown (section 5A). Proponents of MAR schemes must apply for a "licence to take water", under section 5C, which will define both the right to recharge and the right to recover groundwater. For the purpose of the Act, "'take' in relation to water means to remove water from, or reduce the flow of water in, a watercourse, wetland or underground water source […] and includes storing water during, or ancillary to, any of those processes or activities". Moreover, to operate a MAR facility a "licence to construct bores" is required by section 26D.

According to Appendix A of the **MAR Operational Policy**, the issuance of the licence under section-5C – and the approval of the "banking (storage) and recovery of the recharge water" – requires the application of relevant national guidelines (e.g. for recycled water use), a hydrogeological assessment on a case-by-case basis, a previously-approved operating strategy, and relevant health-related documentation for drinking-water use. In this latter regard, a review of the Water Quality Protection Note No. 25: *Land use compatibility in public drinking water source areas* (2004) is under consideration, with a view to accounting for "infiltration or injection of wastewater into the ground" (DoW, 2011).

Lastly, recovery will only be allowed when recharge water is available and water quality requirements are met. If recharge and recovery are undertaken by different operators, the parties must reach an agreement to take water under the existing section-5C licence, ensuring that enough water will be available for recovery during the period of the agreement. In view of the public-property nature of water resources in Australia, the agreement must be approved by the DoW (DoW, 2011).

The **Groundwater Replenishment Project** is a 3-year indirect MAR trial with highly-treated recycled water, and it is meant to investigate drinking-water-supply augmentation through a new climate-independent water source for Perth. The project is implemented by the government-owned Water Corporation, which is the main supplier of water, wastewater and drainage services in Western Australia. Before being recharged to the aquifer, water undergoes an advanced treatment process that uses three main technologies: ultra-filtration, reverse osmosis and ultra-violet filtration. Trials were carried out between November 2010 and December 2012, recharging a total of 2.533 billion litres of recycled water into groundwater. Trials aimed at providing a setting for regulators to develop health and environmental regulations and policies, and at feeding the public debate about groundwater replenishment.

2.4.3 Overview of South Australia and Victoria State legislation

In **South Australia**, under the 2004 **Natural Resources Management Act** (which repeals the 1997 Water Resources Act), the regional Natural Resources Management (NRM) boards are granted special powers to carry out works, including to "divert water to an underground aquifer, dispose of water to a lake, underground aquifer or the sea, or deal with water in any other manner". The **SA Environmental Protection Agency (EPA)** has issued a **Code of Practice for Aquifer Storage and Recovery** in January 2004. The State also has an Environment Protection (Water Quality) Policy, adopted in 2003.

In **Victoria**, the 1989 **Water Act** regulates the underground disposal of matter via bores (section 76), which seems to cover MAR. Water recharged in this manner is recoverable through a regular water abstraction licence (section 51). According to the **Guidelines for MAR – Health and Environmental Risk Management**, published by the Victoria EPA in 2009, MAR is generally regulated by Regional Water Corporations as a delegated responsibility (section 122b) (EPA, 2009). The **Department of Sustainability**

and Environment (DSE) has issued a number of guidance documents on MAR, including the Policies for Managing Section 76 Approvals[19] (DSE, 2010).

2.5 Spain

2.5.1 Applicable EU legislation

Under the **European Union (EU)Water Framework Directive** (No. 2000/60/EC of 23 October 2000) (art. 11), Member States must establish a programme of measures for each river basin district, or for the part of an international river basin district within its territory, in order to achieve the established environmental objectives (art. 4). The programme of measures must take into account the results of the required technical (hydrological and hydrogeological), social and economic analyses (art. 5), which include information on artificial recharge (Annex II, § 2 – *Groundwater*, on the characterization of groundwater bodies).

The programme of measures to achieve the environmental objectives should implement relevant EU directives by adopting 'basic measures' and, where necessary, 'supplementary measures' to be applied locally. If necessary, the programme of measures may refer to national legislation. Among the basic measures to be adopted by Member States, the directive mentions "**controls, including a requirement for prior authorisation of artificial recharge or augmentation of groundwater bodies**" (art. 11.3(f)). In addition, the source water used must not compromise the achievement of the environmental objectives established for the recharged body of groundwater. Artificial aquifer recharge is also mentioned among the supplementary measures that Member States may adopt to achieve the established management and quality objectives (Annex VI – *Lists of measures to be included within the programmes of measures*).

Artificial recharge of aquifers is more specifically regulated under **EU legislation on groundwater pollution**. In particular, Directive No. 80/68/CE of 17 December 1979 requires a special authorisation to be granted by Member States for the artificial recharge of aquifers under their jurisdiction (art. 6). Competent national authorities must ensure compliance with the terms and conditions of the authorization and avoid pollution of groundwater sources from wastewater.

On the other hand, Directive No. 2006/118/CE of 12 December 2006 (known as "**Groundwater daughter Directive**") establishes that all programmes of measures adopted by Member States should include measures to prevent or limit aquifer pollution. It then provides that the input of pollutants resulting from artificial groundwater recharge may be exempted from such measures, if so provided in the programme (art. 6.3). Such exemption is only applicable where efficient monitoring of the bodies of groundwater concerned is in place. In any case, under Directive No. 91/271/EEC of 21 May 1991 concerning **urban wastewater treatment**, the discharge of industrial waste water into collecting systems and urban waste water treatment plants is subject to a special authorisation (art. 11) and "treated wastewater may be reused whenever appropriate" (art. 12).

At the environmental end of the regulatory spectrum, according to Directive No. 85/337/CEE of 27 June 1985, the "artificial recharge of aquifers" is subject to **EIA procedures** where the annual volume of water extracted or recharged is equal to or greater than 10 million cubic meters. For smaller projects, competent national authorities may decide at their discretion, on a case-by-case basis, whether or not to require an EIA, according to parameters or criteria set by each Member State. Countries with experience in "managed aquifer recharge and subsurface storage" (NNC-IAH, 2003) in Europe include

[19] Other documents include, MAR Technical Advisory Notes to Delegates (MAR process summary); Technical Advisory Notes to Delegates: Managed Aquifer Recharge, DSE, 2010; and Amendment (Managed Aquifer Recharge) of Policies for Managing Take and Use Licenses, DSE, 2010.

the Netherlands, Germany, Spain and Hungary. Below is a review of Spanish legislation on artificial groundwater recharge.

2.5.2 Spanish national legislation [20]

The 2001 consolidated **Spanish Water Law** (Royal Decree No. 1/2001 of 20 July 2001 – *Texto Refundido de la Ley de Aguas*) requires an authorisation for treated effluent discharge (art. 101) and regulates the conditions for treated water reuse (*reutilización de aguas depuradas*) (art. 109). A concession is generally required for water reuse, but a simple authorisation shall suffice where the applicant is already authorised to discharge treated effluents. On the other hand, the holder of a water-reuse concession may acquire the relevant authorisation for treated effluent discharge via a contractual arrangement with the holder of said authorization, with the approval of the relevant Basin Authority.

Quality standards are defined according to the intended reuse. Royal Decree No. 1620/2007 of 7 December 2007 establishing the **legal regime for treated water reuse** (*Real Decreto por el que se establece el regimen jurídico de la reutilización de las aguas depuradas*) defines water quality parameters for different uses. For instance, Quality 5.2 is required for the recharge of aquifers through direct injection. Treated wastewater however cannot be reused for human consumption purposes (Steinel, 2012).

Under the 2001 Water Law, the regulation of water works– including underground water storage, aquifer recharge and wastewater treatment (art. 122)– indicates that new water works requiring a concession for a new water use may only commence after obtaining the prescribed concession. The institutional responsibility for water works is shared among the national water resources administration, the **River Basin Organizations**, the regional governments ("Autonomous Communities") and the local governments, depending on the national or local relevance of the works, and on their funding (art. 123).

Guidelines for aquifer recharge are established in Royal Decree n. 907/2007of 6 July 2007 on **hydrological planning regulations** (*Reglamento de la planificación hidrológica*). Each hydrological plan shall include the areas of artificial recharge of groundwater bodies in order to determine the recharge objectives and the procedures to authorize the quantity and quality of water to be recharged. The source water may be recycled water, provided that environmental objectives and public health are not jeopardised (art. 53).

Government Order No. ARM/2656/2008 of 10 September 2008 approving **instructions on hydrological planning** (*Orden por la que se aprueba la Instrucción de Planificación Hidrológica*) requires each hydrological plan to identify different types of artificial recharge, including the recharge of aquifers with effluents (section 3.2.3.4(a)). For each type of recharge, the following shall be identified, where possible: (i) available source water, its origin, its temporary flow regime, its quality, its recharge rate and its chemical composition, (ii) indicators of the hydrogeological behaviour of the aquifer in order to assess its potential response to recharge, the procedures and facilities needed for the recharge operations (above or underground), as well as their lifespan, and (iii) number of artificial recharge points and evolution of recharge volumes in time for each groundwater body.

Some hydrological plans make provisions on artificial groundwater recharge, however most of them do not go into much detail and often refer to national legislation (Duero river basin Hydrological Plan, 2013, and Miño-Sil river basin Hydrological Plan, 2013). The 1998 Cuenca Sur basin Hydrological Plan is briefly reviewed below under the regional legislation of the Andalusia Autonomous Community.

[20]The rich regulation notwithstanding, the general feeling among the Spanish scientific community is that there are not many successful experiences of MAR in the country, as most trials have failed mainly due to technical reasons (personal communication to the author).

2.5.3 Andalusian regional legislation

According to the 2010 **Andalusian Water Law** (Law No. 9/2010 of 30 July 2010), "artificial recharge" is a technique that allows programmed intervention and direct introduction of water in an aquifer, to increase the degree of water availability and to act on water quality; "underground storage" is defined as the temporary storage in a deep aquifer of liquids and gases through artificial recharge techniques (art. 4). In the Andalusia Autonomous Community, the **Executive Council of Andalusia** (*Junta de Andalucía*) is responsible for managed aquifer recharge (art. 8).

The artificial recharge of groundwater bodies or the temporary storage of groundwater is subject to an authorisation from the **competent water authority** (*Consejería competente en materia de agua*). The application must be accompanied by a hydrological report, the justification for the recharge, the volume of water to be recharged, the documentation proving availability and quality of the source water, as well as possible interaction with the aquifer, and the programme of recharge and recovery of stored groundwater. The competent water authority establishes the volume of recoverable water, in accordance with drought plans, if any, and taking into account water security concerns (art. 56).

Concerning recharge facilities and works, the Autonomous Community is competent for groundwater works that do not affect waters outside its jurisdiction, unless they are of general interest for the country (Royal Decree No. 2130/2004 of 29 October 2004 – *Real Decreto sobre traspaso de funciones y servicios de la Administración del Estado a la Comunidad Autónoma de Andalucía en materia de recursos y aprovechamientos hidráulicos (Confederación Hidrográfica del Sur)*). Carrying out artificial groundwater recharge operations without being duly authorised is considered a minor offence under the 2010 Water Law, except where human health risks are involved (art. 106).

The **Cuenca Sur basin Hydrological Plan**, adopted by Royal Decree No. 1664/1998 of 24 July 1998, identifies a number of artificial groundwater recharge areas, including with treated wastewater. Reportedly, however, there has been limited or no follow up on these Plan determinations (personal communication to the author).

3 Regulatory Framework Guidelines for Managed Aquifer Recharge using Treated Wastewater as Source Water

3.1 Scope of a Regulatory Framework For MAR Schemes

MAR in general poses some challenging issues for regulators due to the range of considerations required. Water quantity and quality issues for both source water and receiving groundwater generally need to be addressed in connection with any MAR scheme. Moreover, water quality issues take on added significance when treated wastewater (TWW) is the source water for MAR schemes.

TWW-based **MAR scheme approvals** that may be needed include:

- **harvesting and treatment of source water**, notably, wastewater, taking into account environmental flows and other users of the source water
- **drilling of wells** for investigations, ASR or recovery, and/or construction of infiltration ponds for recharge and storage
- an **environmental impact assessment and clearances** by the relevant authorities.
- **recharge** of TWW to an aquifer, with a view to protecting the aquifer's environmental values, preventing excessive changes in the hydraulic head, and to protecting human health and the environment as a result of the recovery of stored water for the intended end-uses
- **allocation of aquifer storage space**, recognising that this is finite, and may be smaller than the harvestable volume of source water
- **recovery of water from an aquifer**, possibly as a proportion of the cumulative recharge that may depend on the degree to which the aquifer is over-exploited, and taking into account other groundwater users to avoid causing them adverse impacts
- **final use of recovered water**, to ensure that the water quality is fit for the intended final use.

As a result, a regulatory framework for MAR in general will address the **four operational elements characterizing all MAR schemes:**

- **source water harvesting,**
- **aquifer storage and recharge,**
- **the recovery of stored water and**
- **final use.**

The regulatory framework should also be clear about the exclusive **rights and obligations to own, access, manage, recharge, extract and use**

- **MAR source water,**
- **aquifer storage and recharge space and**
- **recovered water.**

Furthermore, a regulatory framework need to address the **water quality** concerns associated with source water, groundwater in the aquifer which is recharged (known as "native" groundwater), and recovered water, for the **protection of human health and the environment**. Not only are such concerns apparent in relation to the harvesting of treated wastewater as MAR source water; they are also relevant as the subsurface component of MAR, while providing water storage and treatment functions, may also add hazards to stored water and create additional environmental problems. Not to mention the adequacy of recovered water quality for the intended end-use, something which is of obvious relevance when the intended end-use of a MAR scheme is for potable water supply, or for uses which call for water of comparable quality.

3.2 Scope, Structure and Key Features of these Guidelines

These Guidelines address the following thematic areas (**themes**)

I. **MAR water resources regulation** issues, related to the water quantity (source water and recovered water) and aquifer storage aspects of MAR schemes which are fed by TWW; (**Theme I**; discussed under section THEME I: Regulatory framework for harvesting of TWW and for recharge, for the recovery of recharged water, and for aquifer storage space allocation)

II. regulation of the **protection of human health and the environment**, involving the water quality aspects of MAR schemes which are fed by TWW, (**Theme II**; discussed under section THEME II: Regulatory framework for the protection of human health and the environment) and

III. **other features** of a regulatory framework for MAR schemes in general, cutting across the aspects of the above mentioned regulations (**Theme III**; discussed under section THEME III: Cross-cutting features of a license-based regulatory framework for MAR schemes).

These Guidelines also touch upon

IV. the **administration, monitoring and enforcement** of the regulatory framework sketched out in these Guidelines (**Theme IV**; discussed under section THEME IV: Administration, monitoring and enforcement of MAR regulatory framework)

The Guidelines are structured around the four above-mentioned principal thematic areas. Inside each thematic area, one or more "**constituent elements**" of a regulatory framework for MAR schemes relying on TWW are singled out and illustrated. The constituent elements may be seen as the components of a future MAR-specific Regulation, and be used as guidance in fleshing out and drafting such Regulation eventually.

Most countries, including in particular those which have been targeted for study in this report, have **water resources management policies and legislation** that provide for water abstraction rights and for wastewater discharge permits, and have introduced mechanisms for allocating water resources between different water uses, users and the environment, including for the disposal of wastewater and the protection of water resources from pollution. They also have regulations on licensing of drillers, issuing permits, licences or concessions to extract groundwater and to discharge wastewater, and some have experience in reducing allocations where extractions exceed the sustainable supply capacity of an aquifer system. However few have **integrated policies or regulations** concerning managed aquifer recharge, for example licencing of MAR operators and of MAR schemes, with conditions and protections to operators for storing and recovering water from aquifers. In particular, the five case study countries reviewed in this report all show **different levels and degrees of integration of administrative requirements** for MAR schemes.

Accordingly, **integrated MAR licencing** is the key feature of the regulatory framework sketched out in these Guidelines, targeting the following MAR operations under the instrument of an **integrated MAR license**:

1) **aquifer storage and recharge** - i.e., the aquifer warehousing/recharge capacity component of MAR schemes regulation, and recharge operations regulation;

2) **recovery of stored/recharged water** from the aquifer - i.e., the groundwater extraction component of MAR schemes regulation;

3) the **public health and environment protection** aspects of recharge and of recovery licencing - i.e., the water quality component of MAR schemes regulation; and

4) **harvesting of source water**, in particular wastewater, with special regard to its treatment to the required standard.

The recovery of stored/recharged water element (see number 2 above) may also be de-coupled from MAR licencing, and be covered instead by a groundwater extraction permit/licence/concession under general water resources legislation.

3.3 THEME I: Regulatory framework for harvesting of TWW and for recharge, for the recovery of recharged water, and for aquifer storage space allocation

Governance of MAR, and its regulatory framework, may be typified by **separate rights**[21]:

(a) to **take source water**

(b) to **store water in an aquifer and to recharge it**, and

(c) to **recover water** from an aquifer and to **put it to a final use**.

The corresponding constituent elements of a regulatory framework for MAR in general, and for MAR schemes using TWW as source water in particular, can be characterized as follows:

3.3.1 Source water (TWW) rights

Arrangements to secure a right to harvest wastewater as source water are likely to proceed in either of two ways:

- via **negotiated contracts** between interested parties or
- via the government grant of a **licence or concession** involving an exclusive user right, where treated wastewater is regarded as public (or State) property (as is the case in some SWIM Partner Countries, notably, Algeria, Israel and Syria).

(a) Harvesting TWW via negotiated contracts

In Spain for example, the water legislation provides that someone who wishes to re-use treated wastewater – including for aquifer recharge – may secure a right to do so through a contract with the holder of an administrative permit for the disposal of wastewater.

Contractual arrangements are outside the reach of regulation, except for aspects linked to the quality of the effluent, and to the standards it must be treated to. These aspects are reverted to later, under THEME II: Regulatory framework for the protection of human health and the environment.

In addition, a regulatory framework for MAR should address and clarify the **ownership of treated wastewater**, as follows:

Element 1A – Wastewater which is harvested via a negotiated contract to be the MAR operator's property

Through a negotiated contract with a wastewater conveyance system operator, MAR scheme operators will seek to secure an exclusive right to the effluent, i.e., a right to treat it and use it as source water for a MAR scheme, to the exclusion of possible claimants to the flow of treated effluent downstream of the point where it is used to be discharged back into the water system. This is **a potentially contentious issue**, particularly in countries where the law has not addressed it. MAR-specific regulation should clarify that treated effluent belongs to the MAR operator, for the exclusive purpose of feeding a MAR

[21]The conceptual model adopted here follows the separation of rights and allocations reflected in Ward, J., and Dillon, P., 2011. *Robust Policy Design for Managed Aquifer Recharge,* Australian Government – National Water Commission, Waterlines Report Series No.38, January 2011

scheme. Again this is particularly applicable in countries where treated wastewater does not have the status of public property.

Box 2: **ARIZONA, *LONG* CASE (1989)**

The traditional rule in the law of prior appropriation prevailing in the Western states of the United States is that a landowner who diverts water from a natural stream may recapture "waste" or "seepage" water from her land but may not reuse "return flow" if doing so would harm downstream junior water users with vested rights in maintaining stream conditions. The influential Arizona Public Service Co. v. Long case in Arizona modified this common law rule, by according rights to effluent to those who treat it. In that case, the Arizona Supreme Court held that, until the state legislature adopts a regulatory scheme for effluent, producers of effluent are entitled to put effluent to any reasonable use. This case involved contracts in which Phoenix-area cities agreed to sell their effluent to utilities that were planning construction of the Palo Verde nuclear power plant. Two ranching companies claimed that they had appropriative rights to surface water flows that largely consisted of the cities' effluent discharges, and that delivering effluent to the utilities would infringe upon these rights. The ranches argued that under Arizona surface water law, the cities had only the right to use the water, not the right to sell unconsumed effluent, since appropriable surface waters belong to the public. Developer John F. Long joined the suit and argued that "the groundwater element of the effluent must be put to reasonable and beneficial reuse for the benefit of the land from which it was withdrawn, and, if reuse is not possible, the effluent must be returned to the common supply, by discharging it into a stream and allowing it to percolate into the ground." In contrast, the cities and utilities contended that the effluent had lost its character as surface water or groundwater, and had become property of which the cities could dispose as they pleased. The Arizona Supreme Court rejected all of these arguments. The court found that effluent is neither surface water nor groundwater until it is returned to the ground in one of those states; it also found that one may have a right to use, but not to own, effluent. Therefore, the cities had the right to put their effluent "to any reasonable use that [they saw] fit," including selling it to the utilities. The court noted that the effluent was subject to appropriation by downstream users if the cities allowed the effluent to return to the waterway. However, the cities were not required to continue discharging the effluent into the river, despite the downstream ranches' appropriative rights. The court further held that the cities had not previously abandoned the effluent by placing it in the waterway, since abandonment statutes apply only when an appropriator fails to withdraw water to which he is entitled. Finally, the court appeared to invite the state legislature to regulate effluent.

(**Source**. Chapman,2005. From Toilet to Tap – The Growing Use of Reclaimed Water and The Legal System's Response, p. 789-793)

(b) Harvesting TWW having public property status

The government's grant of a licence or concession and an exclusive user right in TWW that has the status of public property is governed by general water resources legislation. It is accordingly outside the scope of a MAR-specific regulatory framework. However, the **linkages** between general water resources legislation and a MAR-specific regulatory framework need to be made and reflected in the latter, as follows:

Element 1B – Securing a government licence or concession to harvest TWW having the status of public property

If treated wastewater is regarded as public property, and harvesting for treatment and use is subject to a government licence or concession under general water resources legislation, MAR licencing regulation will require a MAR licence seeker to obtain a concession or licence to harvest and treat wastewater, as a pre-requisite to obtaining a MAR licence.

3.3.2 Aquifer storage and recharge rights

An **aquifer storage/recharge right** represents a unit share in available aquifer warehousing space, defined as a quantum of the net storage capacity. It defines:

- **the right to actively store additional water or**

- **the right to raise the water table**.

Recharge rights in general will not be an issue in over-exploited aquifers, as there would be adequate aquifer storage capacity for multiple MAR operations, and MAR would be welcomed as a means of restoring hydrological equilibrium. In aquifers which are in existing long-term balance or where piezometric levels are trending upwards over a number of years, recharge capacity is finite. Excessive recharge could cause water tables to rise, potentially causing a string of undesirable effects. If adequate source water is available and competition for the storage capacity increases, the rights of existing and new recharge operations will require protection. This can be achieved as follows:

Element 2 – Right to aquifer storage/recharge space to be complemented by the designation of a buffer zone in which concurrent/competing MAR operations are restricted

The specification of **buffer zones** in the recharge right, which would prevent adjacent MAR operations, is one approach to protecting existing operations, and it can be easily monitored.

Element 3 – MAR licence may accommodate granting multiple recharge rights to one MAR operator

To minimize the potential for litigation and reduce operational costs it is also possible to issue recharge rights to a single operator for multiple recharge sites within a defined aquifer zone.

3.3.3 Right to recover water from an aquifer, and to put it to final use

To improve the security of water rights for commercial operators, MAR recovery rights would require institutional differentiation, operating under recovery rules that differ from those governing the rights to extract native groundwater. Mindful of simplicity and parsimony in institutional design, and in order to maintain consistency with prevailing administration processes, the **right to recover stored water could be included in a MAR licence**. This could be expressed as a specified percentage or recharged water. Attachment of a recovery right to an existing MAR licence implies accommodation of a recovery right in the MAR licence, and quantification when this is first granted, or also at a later stage, when actual recovery is contemplated. This approach can be summed up as follows:

Element 4A – Right to recover TWW which has been recharged to an aquifer is accommodated in the MAR licence, and de-coupled from general water resources abstraction regulation.

Secure rights to recover stored water are critical in MAR schemes**.** This is because the main reason for aquifer storage is to enable reliable access to a defined and independently managed volume of water in times of increased water demand or to meet contractual obligations. However, due to mixing of existing or native groundwater and recharged source water, delineation or differentiation of the groundwater available for extraction is likely to be technically infeasible and costly. As a result, under prevailing water resources legislation, including in particular in the five case study countries, **groundwater which has been recharged with TWW is subject to the extraction and management rules of native groundwater**, and is regulated accordingly through abstraction licences or concessions from the un-differentiated groundwater pool. The risk is that the MAR scheme operator wishing to recover groundwater that has been recharged through his/her ingenuity will compete for an abstraction permit with other prospective abstractors from the un-differentiated groundwater pool. The risk can be minimized if the MAR scheme operator is granted by law **priority for an abstraction permit** under general water resources legislation.

This alternative approach to the one outlined earlier can be summed up as follows:

Element 4B– Right to recover treated wastewater which has been recharged to an aquifer is not accommodated in the MAR licence, and is subject to general water resources abstraction regulation. However, a MAR scheme operator wishing to recover recharged groundwater will be granted priority consideration over other prospective abstractors from the pool of mixed native and recharged groundwater.

Recovery and final use of stored water may also be undertaken by a different operator to the one who holds an integrated MAR license – and a groundwater abstraction license or concession, in the scenario depicted in Element 4B. To put it otherwise, if the legislation allows for it (as in Australia), the holder of an integrated MAR license, or of an integrated MAR license-cum-a groundwater abstraction license or concession, may cede his/her recovery and final use rights to a third party. This will be accomplished through a **negotiated agreement** between the parties. In view of the prevailing public-property nature of water resources in a vast majority of countries, however, including in particular all the five case study countries, **endorsement** of the private agreement **by the government water administration** will be a standard requirement (as is the case in the State of Western Australia). This aspect of a regulatory framework for MAR schemes using TWW as source water can be synthesized as:

Element 4C – Should it be lawful to do so, ceding recovery and final use rights to a third party will be subject to endorsement by the MAR licensing authorities

In over-allocated aquifers, the rights to recover recharged water should have a higher level of security than the rights to native groundwater. In practice, the regulatory framework will clarify that the right to recover recharged water will be retained as a matter of priority and will not be subject to reductions applicable to native groundwater allocations if groundwater levels were to decline. This is in recognition of the effort and net benefit contributed by the MAR operator in recharging the aquifer. In conclusion:

Element 5 – Priority will be accorded to recovery of recharged water in times of groundwater extraction restrictions

Box 3: CRITERIA FOR THE DETERMINATION OF RECOVERY RIGHTS

Recovery rights determinations can be made based on the following criteria:

A- the proportion of recharged volume that may be recovered

B- the time period over which recharge credits may be recovered

C- linkages between the volume that may be recovered and the time period (e.g. a depletion rate)

D- the maximum annual recovery rate.

A - proportion of recharged volume that may be recovered

In the case of over-exploited aquifers, where groundwater levels are in long-term decline, recovery from MAR operations could be limited to a specified percentage of recharge volume. The unrecovered balance represents a net contribution towards restoring aquifer hydrological equilibrium. There is no need to limit the percentage of recovery of the volume injected in groundwater systems in long-term hydrologic equilibrium. One hundred percent recovery of recharge volume would be the norm and the long-term goal of effective groundwater management, based on native groundwater extractions and recharge enhancement.

B - time period over which recharge water may be recovered

Major fresh groundwater systems with extensive storage capacity and long residence times would have minimal additional 'natural' discharge as a result of MAR. The full recharge volume should be available for recovery over long time periods. In these aquifers, the rules governing the time period for recovery should be balanced by administrative practicality and the need to provide incentives to conserve water for the future. In contrast, thin coastal aquifers with steep lateral hydraulic gradients are one example of aquifers with high rates of turnover (that is short storage time, determined as the ratio of storage volume to aggregate groundwater discharge including abstraction). As the volume recharged does not persist within the aquifer, the time period to recover recharge credits should be shortened to reflect the short storage time.

C - maximum recovery in any year

Although the maximum cumulative percentage recovered is specified, it is possible to conceive of situations where a MAR operator has accumulated a recovery volume over a number of years and aims to recoup that volume within a single accounting period (nominally one year). In such situations the recovery volume would be much higher than normal recharge or recovery rates. Intense recovery operations over a short duration could cause a significant cone of depression with adverse short-term impacts on adjacent groundwater users (particularly in confined aquifers) or on groundwater dependent ecosystems (particularly in unconfined aquifers). A mitigating approach would restrict the annual extraction volume of a recovery right holder in an over-exploited aquifer and an aquifer with short hydraulic retention time to the maximum annual recharge.

D - inter-aquifer transfers

The question as to whether recharge in one aquifer can result in recovery rights in another is not simple. Inter-aquifer transfers of recovery rights and allocations could be prevented if the aquifers are not hydraulically connected. However, circumstances can occur where a right or allocation to recover recharged MAR water from a fresh aquifer could be transferred to a brackish aquifer, enabling abstraction of brackish water associated with environmental benefits for one or both aquifers. As a principle, the environmental, social and economic benefits and costs for all stakeholders should be considered in determining conditions of inter-aquifer transfer of MAR recovery rights.

(**Source:** Ward, J., and Dillon, P., 2011. *Robust Policy Design for Managed Aquifer Recharge,* Australian Government – National Water Commission, p. 11-18. Ward and Dillon's list of criteria includes the depletion rates for stored water; transfer of recovery entitlements (this is permissible under Australian water legislation) and connected distance of recovery entitlement transfer, gradient, direction and aquifer pressure; and changes in ambient groundwater salinity).

In view of public health and environmental implications, the intended final application of recovered water will require approval. **Approval of intended final use** will be given in the MAR licence, or in the groundwater extraction licence or concession under general water resources legislation, depending on the chosen route (this will be ***Element 6*** (see also in this connection ***Elements 4A, 4B and 4C***).

As a general rule, water quality and quantity monitoring, metering and recording of annual recharge and recovery volumes would be required to verify the protection of the environment at MAR sites. **Monitoring, metering and recording obligations** should therefore be part of the standard terms and conditions of MAR licences, and consequently are the MAR licence holder's responsibility (this will be ***Element 7***).

3.3.4 Accounting for land use, environmental, and human health implications

A MAR licence will include clauses addressing **water quality** aspects of TWW-based MAR schemes, and accounting for the latter's human health and environmental quality implications. These aspects are dealt with in THEME II: Regulatory framework for the protection of human health and the environment below.

In addition, construction of MAR facilities – notably, infiltration ponds, treatment plants – may require a **building permit** under the town and country planning legislation, and an **environmental impact assessment** under the environment protection legislation. To varying degrees, this is the case in the five country case studies. The regulatory framework for TWW-based MAR schemes should capture the **linkages** with such legislation, and weave the relevant required clearances in the fabric of MAR licensing at the inception stage of a MAR scheme, when a MAR licence is applied for, as follows:

Element 8 – Land use planning and environmental impact clearances to be pre-requisites for consideration and grant of a MAR licence

The MAR regulatory framework will require MAR licence seekers to secure the permits and clearances required by land use planning and environmental protection/impact assessment legislation prior to, or at the same time as, seeking a MAR licence. In practice, this will be achieved by requiring that MAR licence seekers include in the relevant application file evidence of compliance with the requirements mandated by the land use planning and the environmental protection/impact assessment legislation, in relation to the various components of MAR schemes, i.e.:

- the harvesting and treatment of wastewater

- the storage and recharge of same in an aquifer
- the recovery of recharged groundwater, and
- the final use of recovered groundwater (see also in this particular connection ***Element 6***).

3.4 THEME II: Regulatory framework for the protection of human health and the environment

Hazards to human health or the environment encountered in MAR projects may originate from:

- **source water for recharge**
- **native groundwater**
- **aquifer minerals reacting with recharge water**
- **by-products of treatment processes or maintenance practices**,

and the key hazards impact:

- the aquifer beyond the attenuation zone (see Box) and hence on other groundwater users and groundwater-dependent ecosystems
- the uses and users of recovered water
- situations where the by-products of MAR water treatments and operations are reused or discharged.

Box 4: ATTENUATION ZONE

The attenuation zone is defined as the aquifer domain enveloping the managed aquifer recharge system, beyond which the water quality always meets the environmental values of the native groundwater. The boundary of the attenuation zone is defined by a common travel time from the recharge source. Following the elapse of that travel time once recharge has ceased, the ambient environmental values of the aquifer will also be met throughout the attenuation zone. In most aquifers, and with appropriate pre-treatment of water to be recharged, the attenuation zone will be small and generally of the order of 20 to 200m from the recharge area or well.

(**Source:** NRMMC–EPHC–NHMRC, 2009, *Australian Guidelines for Water Recycling – Managed Aquifer Recharge*, p.137).

The hazards to human health and the environment from, in particular, the recharge of aquifers with TWW are generally addressed through **legislation for the control and abatement of water pollution** in general, and of groundwater pollution in particular, **from "point" sources**. These include **injection wells** and **infiltration ponds** used in MAR operations. As a result, it is not uncommon for MAR schemes to require a separate permit to discharge treated wastewater to an aquifer, via injection wells or infiltration ponds, under the water pollution control legislation (as under the US federal drinking water legislation, the Arizona state legislation, and the Spanish legislation). Under integrated MAR licensing, however, such requirement can be **attracted and consolidated in the MAR license**. Alternatively, securing a wastewater discharge permit under the water pollution control legislation will be a pre-requisite to obtaining a MAR license, and such permit, or evidence that it will be obtained, must be included in the application file for a MAR license.

The **key hazards** to human health and the environment associated with MAR schemes, however, are not limited to water quality, as they include[22]:

[22] A useful illustration of key hazards and of hazardous by-products are featured in NRMMC–EPHC–NHMRC, 2009, *Australian Guidelines for Water Recycling – Managed Aquifer Recharge,* p.54 and 55, respectively.

- **water pressures and levels**[23]
- **effects on hydrogeological properties** of aquifers and aquitards (low-permeability geological layers that confine or separate aquifers)
- **effects on the ecosystem** and **energy/greenhouse gas considerations**[24].

The central philosophy of available guidelines on the matter is that it is better to **prevent hazardous events** from occurring than to clean up their effects afterwards. The identification, assessment and mitigation of the risks to human health and the environment are therefore at the core of prevention. The relevant instrument is a **risk management plan**.

Box 5: THE MULTIPLE-BARRIER APPROACH TO THE MANAGEMENT OF RISKS

The multiple barrier approach is a key concept in the management of risks to human health and the environment in aquifer recharge. This approach is well established as a means of protecting drinking water quality in Australia (NHMRC–NRMMC 2004) and internationally (WHO 2006). The application of the multiple barrier approach through the managed aquifer recharge risk management plan should encompass every component of the managed aquifer recharge system, and be submitted to the regulator of managed aquifer recharge projects for scrutiny and approval.

(**Source:** NRMMC–EPHC–NHMRC, 2009. *Australian Guidelines for Water Recycling – Managed Aquifer Recharge,* p.23)

The legal requirement to develop a **risk management plan (RMP)** for MAR schemes involving the use of TWW as source water is the cornerstone to regulation of the water quality aspects of such schemes (this will be ***Element 9***). The requirement of a RMP:

- will feature in the regulatory framework as a standard legal requirement of a MAR licence application file, for consideration and endorsement by MAR regulators,
- will be incorporated in the MAR licence, and
- in view of the breadth of scope, will attract and override comparable RMP requirements featured in the water pollution control legislation (the assessment of risk connected to the discharge of wastewater to an aquifer, for example, features in the Water Act of South Africa (1998)'s water abstraction and wastewater discharge licensing provisions).

After it has been approved and incorporated in the MAR licence, the **RMP will become binding** for the MAR licence holder, and will be the source of enforceable obligations.

Box 6: KEY FEATURES OF A RISK MANAGEMENT PLAN FOR MAR SCHEMES

A managed aquifer recharge risk management plan is a documented system for the management of aquifer recharge. It should include the following features:

- register of relevant regulatory requirements
- names and contact details of stakeholders
- a process diagram of the entire managed aquifer recharge system (capture, pre-treatment, injection, storage, recovery, post-treatment and end use)
- operational procedures and process controls
- critical control points, quality control points and associated critical limits

[23] Hydraulic head impacts may extend considerably further than water-quality impacts. This is most pronounced in confined aquifers, where hydraulic effects can propagate around 200 times further than the water-quality effects (NRMMC–EPHC–NHMRC, 2009. *Australian Guidelines for Water Recycling – Managed Aquifer Recharge,* p.137)

[24] Energy and greenhouse gas considerations are illustrated in NRMMC–EPHC–NHMRC, 2009, *Australian Guidelines for Water Recycling – Managed Aquifer Recharge,* p. 110-111.

- incident and emergency response procedures
- training programs and records for employees and contractors
- monitoring information (baseline, operational, validation and verification of data)
- communication with authorities concerning system performance and monitoring results

In particular:

A. Assessment of the MAR system

To identify and manage all health and environmental hazards and associated risks in a managed aquifer recharge system, proponents must submit evidence of a thorough documented knowledge of the entire managed aquifer recharge system, from sources of recharged water to uses of recovered water and the fate of recharged water in the aquifer, including the potential effect of hazardous events on treatment systems that may affect human health and the environment, such as:

- storms
- sewer overflows
- power failures
- illegal disposal of contaminants.

The method used to identify and assess hazards must be structured, consistent and comprehensive. Hazard identification typically involves the following steps that help to classify the managed aquifer recharge system:

- hazard identification
- dose–response and exposure assessment of the identified hazards[25]
- risk characterisation.

B. Preventive measures for recycled water management

Preventive measures for the management of recycled water in general, and of sewage effluent and wastewater in particular, include all actions, activities and processes used to:

- exclude hazards (exclusion barriers)
- reduce hazard concentrations (e.g. by treatment above or below ground)
- manage water usage (end-use restriction barrier).

In order of priority, a RMP for MAR schemes contemplating the use of sewage effluent/ wastewater as MAR source water would cover:

- treatment (e.g. engineered processes and time in aquifer storage)
- management at the end use (e.g. withholding periods or irrigation method selection) to minimize exposure.

In this same context, a RMP is to include:

- *Critical* and *non-critical control points* (also referred to as *quality control points*), based on operational monitoring requirements or on appropriate water quality parameters (e.g. indicators such as turbidity in case the recovered water is used for drinking), and
- The *critical limit*, which is the maximum (or minimum) value to which a hazard must be controlled at a critical control point to reduce its risk to an acceptably low (or high) level.

The adopted critical control points, critical limits and target criteria for risk management form the basis of the operational procedures and process controls that are adopted (discussed below).

C. Operational procedures and process control

During the operation of a MAR system, operational procedures and process control monitoring is performed to

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[25]Hazardous events, such as spills in an urban storm water catchment or failure of a wastewater treatment plant, may lead to predictable changes in hazard concentrations and exposure. Because many hazards do not have established dose–response relationships, alternative methods may be applied. Aquifer characterisation will be necessary to estimate the fate of recharged water, and its potential to affect other groundwater users or groundwater-affected ecosystems (NRMMC–EPHC–NHMRC, 2009. *Australian Guidelines for Water Recycling – Managed Aquifer Recharge,* p. 25)

check the performance of preventive measures discussed above. The procedures should be designed to identify non-conformance with target criteria and to indicate a decline in system performance.

Operational monitoring does not solely encompass treatment indicators; it should also include aspects of the system that require regular checking to ensure that preventive measures are applied. Examples include operating pressures, groundwater levels and subsurface residence times.

D. Verification of water quality and environmental performance

The above operational procedures and process controls verify that the MAR system poses very low (acceptable) risks to human health and the environment. Verification of the recovered water quality assesses the overall performance of the MAR system in relation to specific uses of the water.

A RMP would include provision for decommissioning of the MAR operation, including the verification monitoring that needs to be undertaken until the aquifer has been restored to its ambient environmental values.

E. Management of incidents and emergencies

Responses to incidents or emergencies can compromise the operation of a MAR system. The development of preventive measures appropriate to the risks should be documented as part of items A and B in the system's RMP.

Management of incidents and emergencies for MAR operations would include response to:

- disruption to pre-treatment or post-treatment processes that result in the production of nonconforming water
- disruption to power supplies that affects treatment or injection and recovery systems
- protocols for communication between suppliers, users and other stakeholders
- any other incident that could affect the safe operation of a MAR operation.

F. Operator, contractor and end user awareness and training

All operators, contractors and end users who work with MAR systems must be given appropriate training. Training and awareness programs for such systems should include induction programs for new employees, MAR site visitors and contractors, and employee training in the principles of risk management. All employees should be aware that any observable problems must be reported in a timely manner, instead of waiting until the equipment or process fails.

G. Community involvement and awareness

Community consultation is essential in planning water recycling for use in MAR schemes. Community engagement should begin during the development of the RMP for the MAR scheme. However, engagement will vary with the scheme's nature, location and scale, and the risks involved. Establishing appropriate processes for engaging and communicating with stakeholders is an important step in the planning of a MAR scheme and, in particular, in the development of a RMP.

H. Validation, research and development

Validation involves investigating the effectiveness of preventive measures in reducing risks posed by hazards or hazardous events discussed at (B) above. It can be achieved by obtaining evidence about the performance of preventive measures, and by making sure that information supporting the MAR RMP is correct.

Validation plays an important role during establishment of a MAR system. For example, during the commissioning phase for a new system, the operator needs to demonstrate the system's capability to consistently produce recovered water of the quality required for the planned uses. Validation is also required whenever new processes or equipment are introduced, or when significant changes to the MAR system take place.

Formal investigation or research may be needed if there is insufficient knowledge of the effectiveness or reliability of the barriers within the system to maintain recovered water quality within critical limits, or if the environmental impact of hazards is unknown.

I. Documentation and reporting

The RMP will contain most of the recorded documentation relating to the MAR system's operation, including monitoring information, as proof of plan compliance.

Routine reporting of operational monitoring data should be kept to the minimum required to identify adverse trends or declining operational performance. Evaluation of results and internal and external audits (discussed below) should be reported to everyone responsible for operational procedures and process controls.

Routine external reporting requirements for regulators would be also specified in the MAR licence/permit.

J. Evaluation and audit

Where third party certification does not exist, the RMP would be audited regularly. This should preferably be done by an external party with appropriate certifications (if available) or by the regulator; internal auditing is also an option. Auditing is essential to ensure the maintenance of standards and encourage continuous improvement (see the next item below). Based on the results, the evaluation period may stretch beyond an initial one year; however, to account for changes in the source-water conditions and changes in pressures on the aquifer system, the period should not exceed five years.

K. Review and continuous improvement

A RMP should be internally reviewed periodically, to ensure that it accurately reflects the current understanding of the system's risks and controls discussed at (A) and (B) above. Reviews should be overseen by the scheme operator and should include all components of the system, including end uses. All monitoring data, particularly environmental parameters subject to long-term degradation (e.g. groundwater quality) should be included.

The outcome of each review should be documented. It will inform the periodic review of a MAR licence/permit (see III below), and may result in the variation of the latter's terms and conditions as to, in particular, required improvements in operational procedures and process controls, including a timeframe for implementation before the next review is due.

(**Source:** NRMMC–EPHC–NHMRC, 2009. *Australian Guidelines for Water Recycling – Managed Aquifer Recharge,* p. 23-32)

3.5 THEME III: Cross-cutting features of a license-based regulatory framework for MAR schemes

A licence-based regulatory framework for MAR schemes in general, and for MAR schemes fed by TWW in particular would, in addition to the MAR-specific features illustrated at I and II above, include a number of **additional, more general features**, cutting across the quantity and quality aspects of MAR regulation, as follows:

Element 10 – periodic review of MAR licence, and variation upon review

Periodic review and, if warranted, **adjustment** are standard mandatory features of RMPs. The documented outcome of the performance review of a RMP will trigger and inform a review of the licence for the relevant MAR scheme, and the adjustment (technically a "**variation**") of its terms and conditions as warranted by the review. More in general, the **review of a MAR licence** at regular intervals of time, or whenever a change occurs in the circumstances of the relevant MAR scheme, and adjustment to reflect the outcome of the review, would be a standard feature of the MAR regulatory framework.

Element 11 – suspension and termination of MAR licence

When the circumstances warrant action by the regulator – notably, when the MAR scheme fails to meet the terms, conditions and requirements of a MAR licence, or does not conform with other statutory obligations or requirements – the regulator would have the authority to **suspend** a MAR licence for the time required to rectify or remedy non-conformance.

The regulator will have authority to **terminate** a MAR licence in the following circumstances:

- at the request of the MAR scheme operator, or

- at the regulator's initiative, when there is persistent non-conformance of a MAR scheme with the terms, conditions and requirements of a MAR licence, or with other statutory obligations or requirements.

These **review and adjustment, suspension and termination authorities** will be provided for in the MAR regulatory framework.

An important aspect of the termination of a MAR licence is the **de-commissioning** of the relevant MAR scheme, something that the scheme's Risk Management Plan is to provide for (see Box 6 at D)

3.6 THEME IV: Administration, monitoring and enforcement of MAR regulatory framework

Under the circumstances prevailing in most countries including, in particular, the five case study countries, a number of mostly governmental but also non-governmental actors partake of the **administration, monitoring and enforcement** of the regulatory framework for TWW-sourced MAR schemes sketched out in these Guidelines:

- **water resources management authorities** are responsible for water access/quantity allocations in general, and for the grant of licences or concessions to take TWW in particular, when the latter is regarded as public property – see ***Element 1B***;
- **environment protection agencies** are responsible for environmental impact assessments, environmental water quality issues, and probably approvals to recharge;
- **local government** is responsible for land use/urban planning and development approvals;
- **health authorities** are responsible for permits for final use of recovered groundwater, and have a say in all phases of the MAR scheme approval and oversight cycle involving public health issues; and
- **water utilities** are also involved when, in particular, treated sewage is the source water for a MAR scheme, or when their drinking water mains or non-potable supply mains are used to distribute recovered water.

Ensuring **coordination**, and bringing about **consistency of administration, monitoring and enforcement** across the multiple government authorities (and non-governmental actors in the case of private or mixed public/private water utilities) involved at different levels in the approval and oversight of MAR schemes, is the **challenge**. To a degree, this challenge can be met by:

- **designating a lead government agency/department** to bear principal responsibility for the administration, monitoring and enforcement of the MAR-specific regulatory framework sketched out in these Guidelines, and
- **requiring prior consultation** with non-lead government agencies/departments, at points in the MAR scheme approval and oversight cycle where such input is critical.

The government **water resources authorities** would seem to be the best placed to undertake the lead role in the administration of the regulatory package presented in these Guidelines, with the concurrence of the **health and the environment protection authorities**. In particular, and in view of the overriding public health implications of MAR schemes involving the use of TWW as source water, the water authorities will be under a duty to consult with the health authorities in the administration of the health protection elements of the regulatory framework described. Moreover, water authorities will be bound by the advice of the health authorities, under threat of annulment of MAR licencing decisions on appeal before the courts.

Monitoring and enforcement will require the concerted effort of all actors involved, with the water resources authorities playing the lead and a coordinating role. As indicated in ***Element 7***, monitoring of MAR scheme performance is also the responsibility of the MAR licence holder.

Box 7: **RESPONSIBLE AGENCIES AND OTHER MAR-RELEVANT ACTORS IN AUSTRALIA**

Water resources management authorities at state and/or regional level are normally responsible for water quantity entitlements; environment protection agencies are normally responsible for water quality and approvals to recharge; local government is responsible for planning and development approvals; health commissions are responsible for permits for use; and water utilities will also be involved if reclaimed water is a source or their drinking water mains or non-potable supply mains are used to distribute recovered water. In some jurisdictions there are also state planning departments, plumbing industry commissions, storm water management authorities and collectives of local governments in a catchment that will also have a consultative role in decision making

(**Source:** Dillon, P., Pavelic, P., Page, D., Beringen, H., Ward, J., 2009. *Managed Aquifer Recharge: an Introduction*, p.41)

Element 12 – enforcement of MAR licence terms and conditions, and of regulatory requirements in general

Enforcement of the terms and conditions of a MAR licence, and of MAR regulatory requirements in general, will generally involve the **suspension** or **termination** of the MAR licence, and the consequential **de-commissioning** of the relevant scheme. However, the MAR regulatory framework will make allowance for the MAR scheme operator to make mends, and to conform with the legal requirements of the licence and of other regulatory requirements within a set deadline.

Enforcement of final use restrictions of recovered water will, in addition, involve the **destruction of the non-conforming end-product**.

Box 8: **GROUNDWATER USE RESTRICTIONS ENFORCED AGAINST ZUCCHINI SQUASH GROWERS IN ISRAEL**

In Israel, in October 2013 fifteen acres of zucchini squash in the Central Region were destroyed by an order of the Health Ministry on grounds of non-conformance of the extracted groundwater to the quality standards required for that particular use. Moreover, the irrigation use was not supported by a required Health Ministry permit. While the case did not involve the use of TWW-recharged groundwater, it is nonetheless a useful illustration of the enforcement of regulatory restrictions in a situation bearing a close analogy to the use of TWW-recharged groundwater.

(**Source:** personal communication to the author)

4 Conclusions and Recommendations

The use of adequately treated wastewater in the managed recharge of aquifers, with a view to augmenting available water supplies and to providing environmental benefits, and the recovery of TWW stored in an aquifer, tend to be the province of water abstraction and wastewater discharge regulations, with land use planning and environmental impact assessment regulations complementing the available regulatory framework in a majority of countries where MAR with TWW is practised (e.g., Israel, South Africa, Arizona, Western Australia) or just contemplated and regulated as an option (e.g., Spain). Arrangements for the governmental administration, monitoring and eventual enforcement of available regulations follow a similarly divided and compartmentalized pattern.

With a view to overcoming the prevailing compartmentalized approach of available regulatory frameworks and of the relevant administration, **an integrated approach hinging on integrated MAR licensing, and on the harmonization of other strands of regulation with MAR licensing, is recommended**. In parallel, **re-alignment of government regulatory roles along comparable lines is also recommended.**

It **is further recommended** that this report and, in particular, the Guidelines be taken up by SWIM Partner Countries in devising **a policy and a regulatory framework** which facilitates the development of TWW-sourced MAR as a viable option to meet the challenge of dwindling water supplies, of a quality suited to different uses.

In view of the novelty, complexity, and range of considerations involved, the Guidelines in particular should be seen, interpreted and applied as work-in-progress. It **is recommended** therefore that they **be reviewed and fine-tuned** as SWIM PCs develop their own regulatory framework based on their national specificities, and put as a result the Guidelines to the test.

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