Sixty years of progress in research and practice of Managed Aquifer Recharge

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Open for extension by other co-authors

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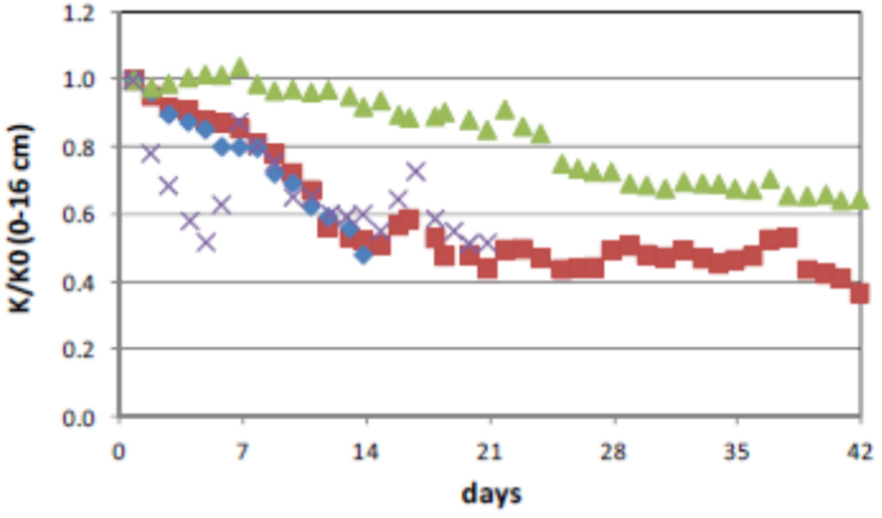
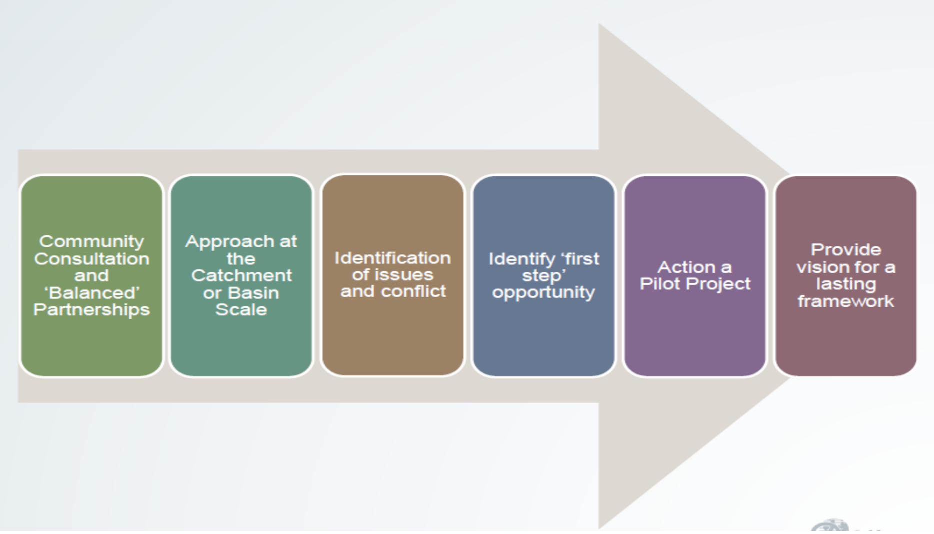


Contents

- What is MAR ?
- How much does MAR contribute to global water supplies ?
- Progress in research
- Models of progress
- Key messages
- What next?



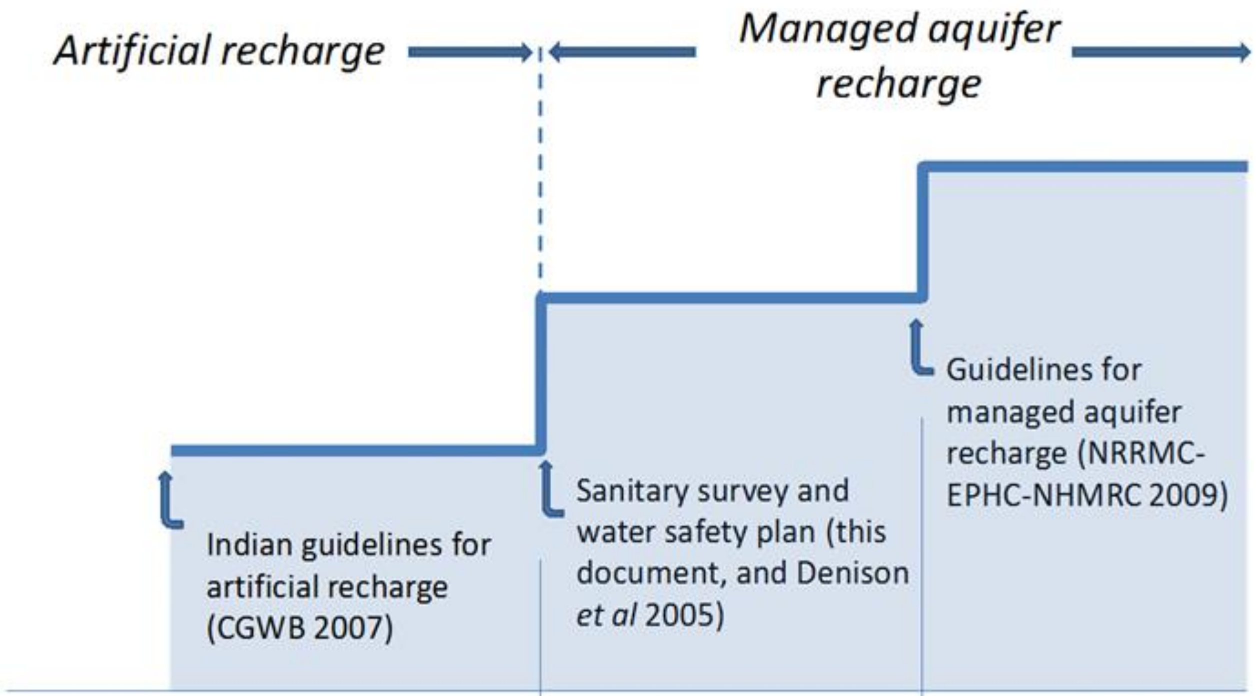
Images courtesy of Bob Bower, Golder Assocs, Hinds/Hekeao MAR pilot project, Canterbury Plains, New Zealand

Types of groundwater recharge augmentation, showing evolution from unintentional to unmanaged and now managed aquifer recharge (adapted from NRMMC,EPHC & NHMRC 2009)

Unintentional Recharge Enhancement	Unmanaged Recharge (for disposal)	Managed Aquifer Recharge (for recovery)
• Clearing of deep rooted vegetation, or soil tillage • Irrigation deep seepage • Leakage from water pipes and sewers	• Stormwater drainage wells and sumps • Septic tank leach fields • Mining and industrial water disposal to sumps • Drainage water from construction pits	• Bank filtration • Streambed weirs • Infiltration basins • Reservoir releases • Injection wells

Terminology is important

- Artificial recharge – old name for MAR but still used if water quality is not being managed



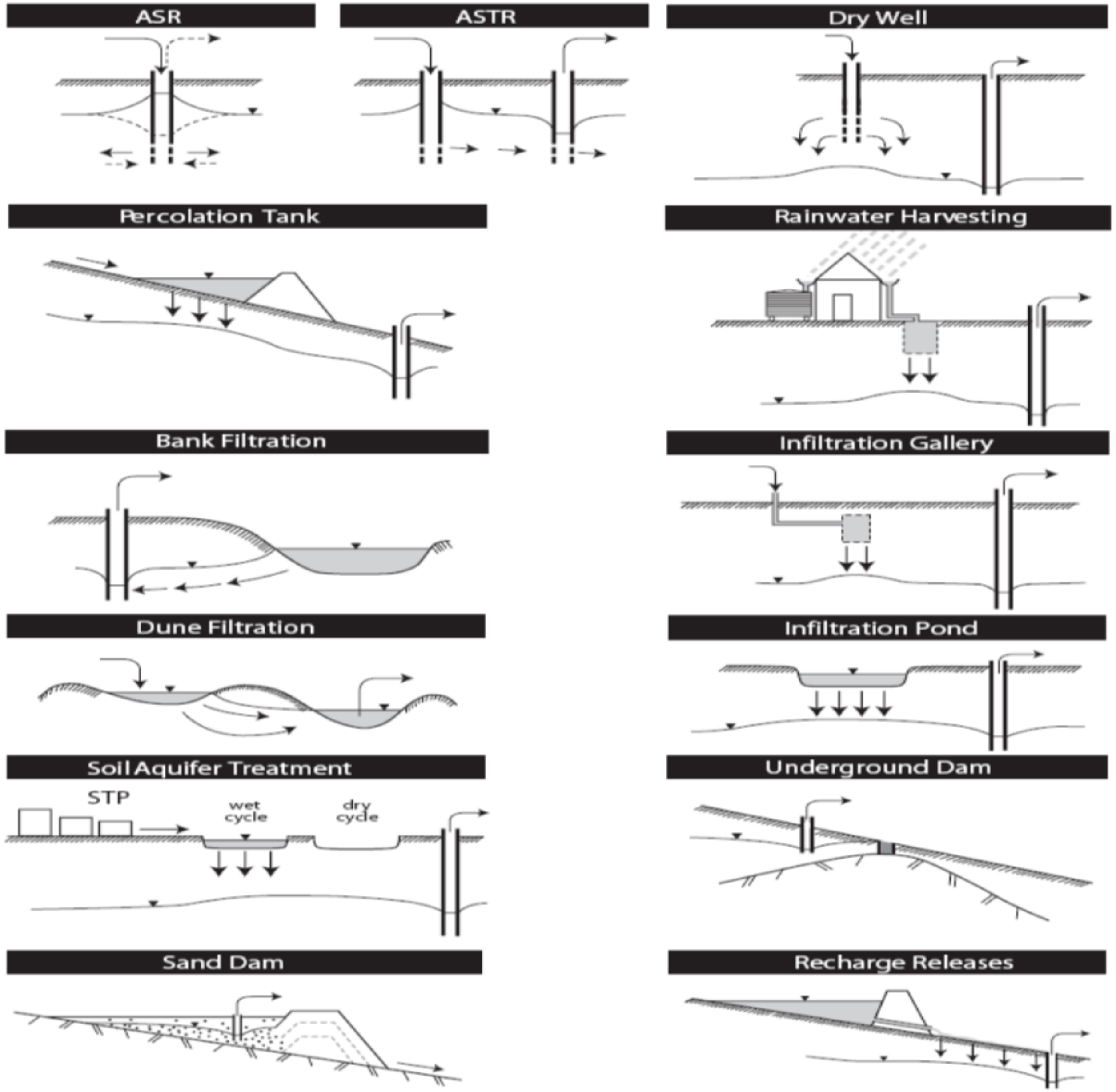
Water quality focus :	Not explicit	Public health	Public health & environment
Risk assessment :	None	Qualitative	Quantitative
Level of safety :	Unknown	Safer	Safe

Dillon P., Vanderzalm, J., Sidhu, J., Page, D., Chadha, D. (2014). A Water Quality Guide to Managed Aquifer Recharge in India. CSIRO Land and Water and UNESCO Report of AusAID PSLP Project ROU 14476. https://publications.csiro.au/rpr/pub?pid=csiro:EP149116 (accessed 26 Sept 2016)

Terminology is important

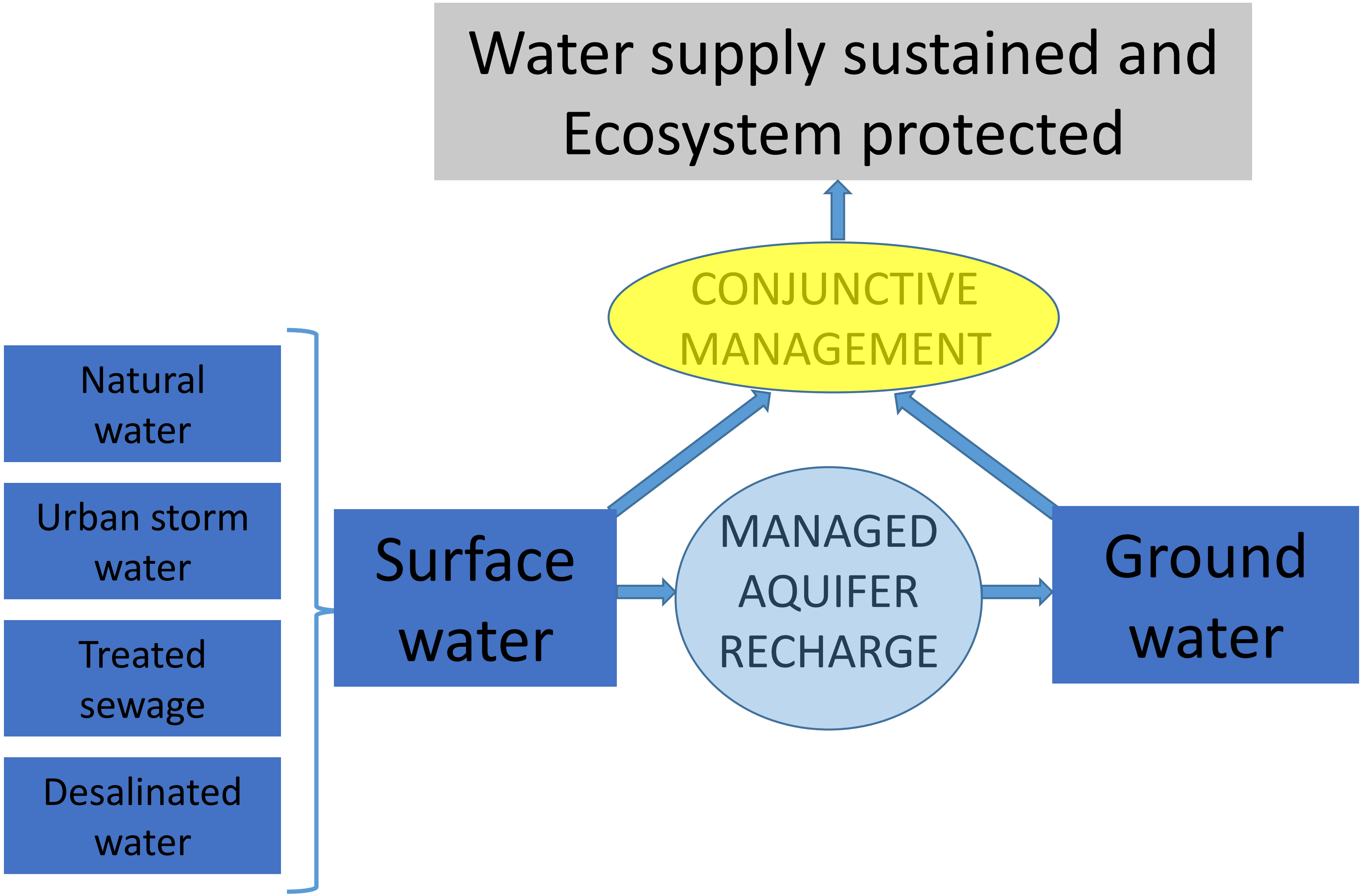
- Artificial recharge – old name for MAR but still used if water quality is not being managed

- Terms for types of MAR –use consistent terms because these have important distinctions for water quality regulators and we want consistent governance

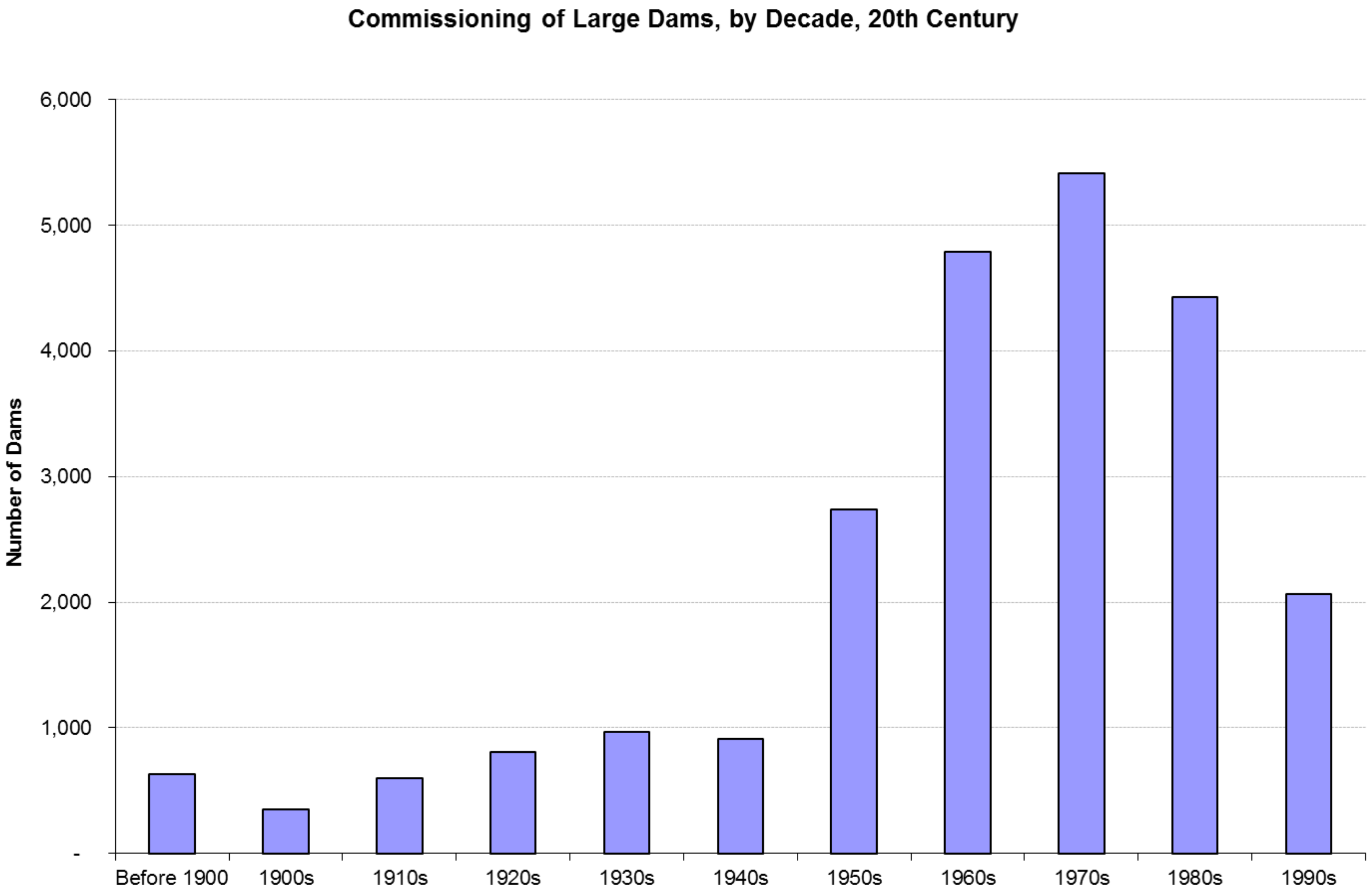


Dillon (2005) Future management of aquifer recharge. Hydrogeology J , 13 (1) 313-316.

Integrated water resources management through MAR and conjunctive use



Large dams

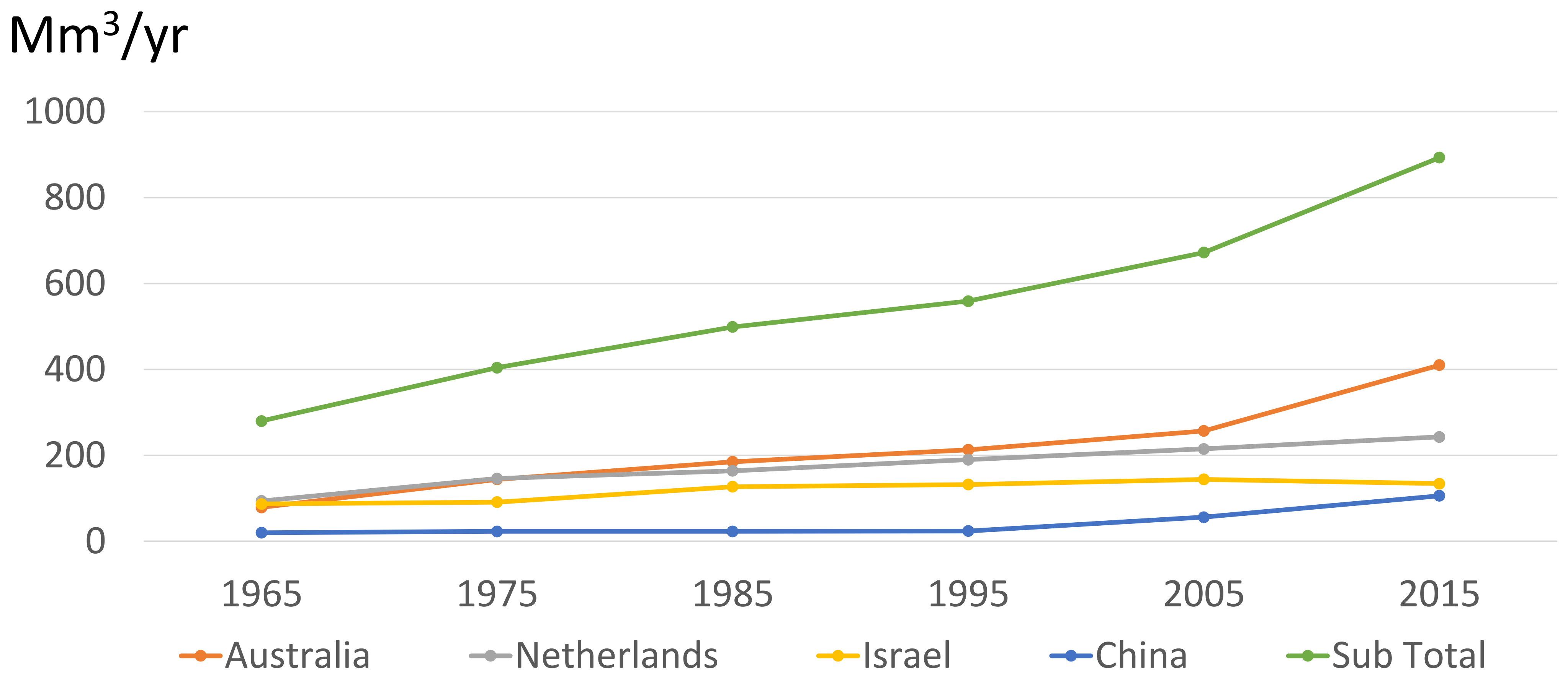


- global capacity 19,000 km^3
- Ave residence time of water 3.3 yrs
- Site saturation
- Ecological impacts
- Siltation
- Equity of benefits?
- Unpopular

BUT

- Existing dams are a significant advantage for implementing subsurface storage augmentation

Growth in Managed Aquifer Recharge (for selected countries) 1965-2015



Growth in Managed Aquifer Recharge 1965-2015 (in million cubic metres / year)

Date	Australia	Netherlands	Israel	China	Sub Total	Projected Total
1965	79	94	87	20	280	
1975	144	146	91	23	404	
1985	185	164	127	23	499	
1995	213	190	132	24	559	
2005	257	215	144	56	672	
2015	410	243	134	106	893	7,100 *
Annual Groundwater use 2010-15	5,000	944	470	112,000	118,414	982,000
MAR as % ground-water use	8.0%	25.4%	28.5%	0.1%	0.8%	0.7%

* Projected total includes published values for some sites in USA 4500, Germany 870, Spain 380 Mm^3/yr, and a conservative estimate for India 500 Mm^3/yr.

MAR in perspective

	km^3/yr	
• Natural recharge	12,000	(Margat 2008)
• Groundwater use	982	(Margat & van der Gun 2013)
• Groundwater depletion	145	(Konikow 2011)
• Managed aquifer recharge	7	(this analysis)
• Seawater desalination	10	(UNESCO 2008)
• Turnover of dams	4-6,000	(Pacific Institute 2003)

Papers presented at ISMARs by topic

Date	1988	1994	1998	2002	2005	2007	2010	2013	2016	All	%
ISMAR	ARG1	ARG2	TISAR	ISAR4	ISMAR5	ISMAR6	ISMAR7	ISMAR8	ISMAR9		
Location	Anaheim	Orlando	Amster-dam	Adelaide	Berlin	Phoenix*	Abu Dhabi	Beijing	Mexico City		
Hydraulics- clogging		3		9	7	3	4	10	6	42	6
Hydraulics- recovery				12	24	3	12	15	3	69	10
Geochemistry		8		9	14	4	10	13	6	64	9
Microbiology		1		5	5	2	1	4	0	18	3
Organic chemistry		5		6	12	5	7	11	2	48	7
Water Reuse & stormwater		13		7	7	3	17	2	4	53	8
Infiltration systems		9		15	19	7	9		9	68	10
Injection wells		14		8	16	4	9	1	4	56	8
Case studies		27		9	28	9	29	25	28	155	23
salinity/subsidence control		3		3		1	2	8	2	19	3
thermal applications		1		2				2	0	5	1
Site selection				6		1	1	6	4	18	3
Governance / Socio-economics				0	1	7	5	14	8	35	5
Integration/Conj use				0		3	9	11	12	35	5
Other				0					0	0	0
Total	0	84	0	91	133	52	115	122	88	685	100

* Phoenix excludes posters

Progress in Research

Tools have improved out of sight..

- Computers and modelling, geostatistics, spreadsheets,
- Materials – well casing, screens, valves, pumps, drilling eg vibrocore
- Water treatment – activated carbon, ozonation, reverse osmosis, membrane bioreactor, deoxygenation
- Logging – geophysics- down hole, surface, airborne, down hole flow logging
- Monitoring and analysis – trace organics, viruses (PCR), BDOC (biodegradable dissolved organic carbon), particulate particle size distributions, isotope analyses C, N, S, O, H etc
- Pressure transducers, probes, flow meters, loggers, SCADA – control systems
- Risk assessment methodology

enabling greater scientific insight..

- Hydraulics, clogging, recovery efficiency
- Fate of constituents
- Geochemistry
- Microbial ecology

A common evolution of MAR

IAH-MAR has a role

- Idea in response to a problem or opportunity
- Pilot project
  - It works – replicate
  - It fails – forget MAR for a generation it doesn't work
- Scale up
- Develop guidelines, policies
- Integrate in water supply & groundwater management plans
- Form communities of practice
- Farmer participation in alluvial systems (eg India, Spain)
- Basin management plans

Needs

Information

- Citable references on innovative projects
- Measurement of water quantity and quality at MAR sites
- Breakdown of economics of MAR sites
- Global inventory of MAR
- Maps to show potential for MAR
- Communities of practice to share experience

Scientific advances

- Standardised methods to predict clogging
- Standardised validation procedures for pathogen removal
- Improved prediction of contaminant removal and mobilization in aquifers
- Cheaper aquifer characterization and ecosystem indices

Governance

- Implementation of groundwater management plans that recognize role of MAR
- Water quality guidance based on risk management/water safety
- Encouragement of water banking for water security in drought, climate change
- Encouragement of conjunctive use of g/w and s/w
- Strengthen IWM in urban areas, incl stormwater, treated waste water
- Link water to energy, food, and land planning to account for multi-sectoral benefits
- Support for community cooperative MAR development and maintenance

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IAH-MAR Working Groups

- MAR for Development – Yan Zheng
- Economics of MAR- Andrew Ross
- Global MAR Inventory – Catalin Stefan & Nienke Ansems (+60 yrs history-PD& Pieter Stuyfzand)
- ?
- China – Weiping Wang; Italy - Rudy Russito; Australia – Greg Ingleton & Euan Hinds;
- Management of Clogging – Russell Martin
- ?
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- ?
- Call to action on GW Management – Tim Parker
- *Policy and Economics – Sharon Megdal*
- *MAR as adaption to climate change- Bridget Scanlon*
- MAR to MARket – Enrique Fernandez Escalante

Needs

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- 2.2.1 Citable references on innovative projects ……………………………
- Measurement of water quantity and quality at MAR sites
- 2.2.2 Breakdown of economics of MAR sites ……………………………
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Focus Area #2.2 Strategies for MAR

General objective:

Improve security and quality of water supplies especially in water scarce areas under climate change and population growth

Specific Objectives:

1. Integrate managed aquifer recharge into IWRM to address effects of locally changing climate (WG4), population and food production (WG2, WG3, & joint proposal IAH-UNESCO -> GRIPP)…
2. Develop and apply methods to assess impacts of recharge structures on water availability and quality, social and economic resilience and local ecosystems (WG2,WG3, WG6, ISMAR9 (SWARM J and J Water thematic issues)
3. Evaluate the and benefits of recycling of appropriately treated urban waste and storm water for aquifer recharge (WG5, ISMAR9 (J Water thematic issue)…
4. Enhance governance capacities and institutional and legal frameworks to aid effective MAR implementation. (WG2, MAR GLs India .. Dillon P., Vanderzalm, J., Sidhu, J., Page, D., Chadha, D. (2014). A Water Quality Guide to Managed Aquifer Recharge in India. CSIRO Land and Water and UNESCO Report of AusAID PSLP Project ROU 14476. https://publications.csiro.au/rpr/pub?pid=csiro:EP149116 ..+WG3 China) do more?
5. Develop a scientific basis for the prevention and management of clogging (WG1)

Conclusions - the journey so far

The last 60 years has seen a huge growth in MAR based on sound interdisciplinary science.

MAR currently compensates for 5% of global groundwater depletion, and good management would see that percentage rise for two reasons.

MAR reduces net groundwater use by only 0.7%, and it is a trivial 0.06% in comparison with natural recharge. However its done where it is useful and critically needed.

There are more people to feed and climate variability in many places is reducing natural recharge, increasing evaporation and water use. **It would be irresponsible not to consider buffering of storage below ground**. Resilient water supplies are fundamental so MAR is no longer exotic, it’s a mainstream groundwater management tool and **should be used as inducement for demand management, not as a substitute**.

In 60 years artificial recharge has transitioned from trial and error to rigorously investigated, and from unmanaged to managed. Soil and aquifers that once were regarded as passive are now seen as bioreactors and aquifer hydrogeochemistry and ecology recognized as important. Success is no longer random, its expected, unless dismissed early in site investigations.

Conclusions - the journey ahead

Trends:

- More water banking for drought and water security
- More use of urban wastewaters
- Engineered and natural treatment methods to complement soil and aquifer targets
- Community based MAR in alluvial systems with technical support
- Ongoing research on information gaps and synthesis of knowledge

For IAH MAR Commission:

- Continue to promote exchange of information of benefit to water suppliers and users, water resources managers, environmental and health regulators, planners, financial institutions and communities
- Continue to foster interdisciplinary research and sharing between researchers and all stakeholders.
- Dispel myths, and divergent policies in place around the world that are not supported by science, and encourage good practices so that all new MAR operations are sustainable.

International Association of Hydrogeologists

Commission on Managing Aquifer Recharge

IAH –MAR www.iah.org/recharge

Plenary 6.30-7.30pm
today in this room
ALL WELCOME

Aim: Safe, sustainable recharge enhancement

Methods: web site, publications database, email list, conferences, projects, working groups, workshops

Outputs:

- UNESCO publications – '*Strategies to enhance recharge in arid and semi-arid areas'* , *'..managing aquifer recharge, discharge and storage equilibrium'*
- *Working groups -Monograph on clogging (Russell Martin (ed)), governance & economics (J Water special issue 2015), MAR for development (workshop at ISMAR9, 2016), International inventory of MAR (with IGRAC and EU),*
- ISMAR9, training programs

CoChairs: Peter Dillon, Weiping Wang, Enrique Fernandez Escalante