www.csiro.au

Managed aquifer recharge -examples of success

Water for a Healthy Country Flagship Program

Peter Dillon

Leader, Water Recycling and Diversified Supplies

CSIRO Land & Water

University of Dhaka, Acacia Water,

Govt of Bangladesh and UNICEF

24 Feb 2011

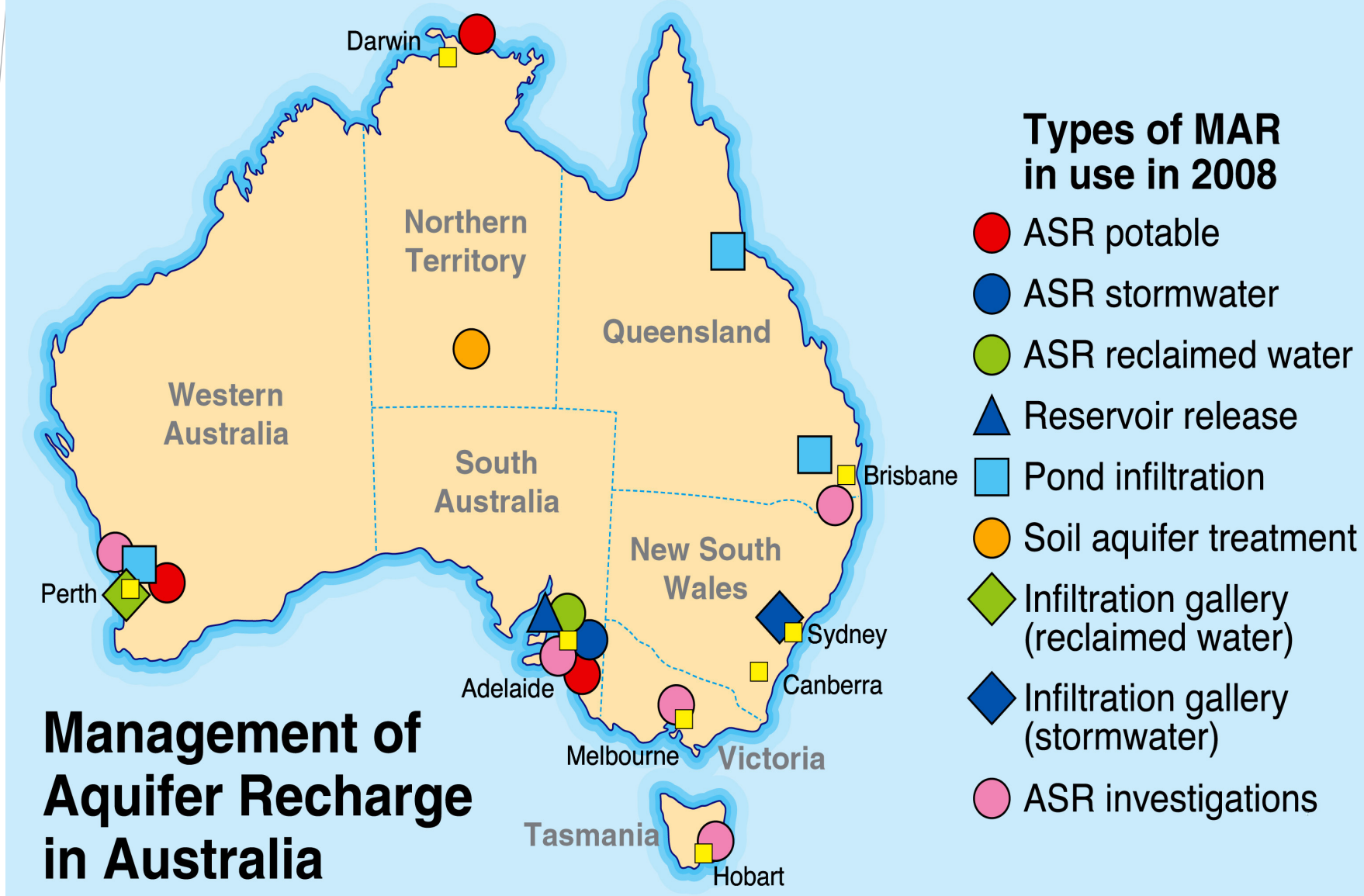
National Research FLAGSHIPS

CSIRO

Contents

- Brief history of start of MAR in Australia
- Six factors that facilitate successful application of MAR with Australian examples
- Conclusions
- IAH Commission on MAR and UNESCO-IAH MAR Network

Locations and types of MAR in Australia in 2008



Burdekin Delta, Queensland Australia

Sand dams

Relining recharge pit

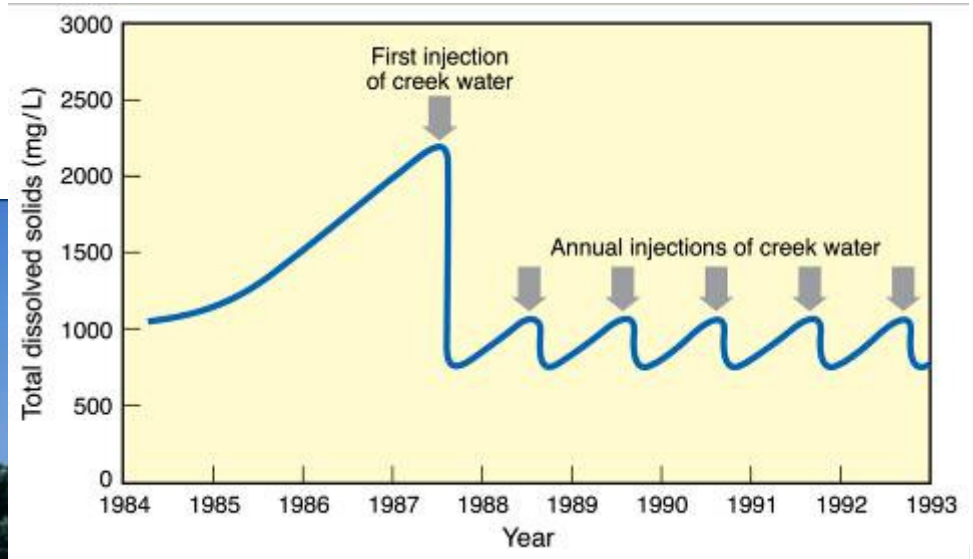
Burdekin Delta, Queensland Australia

Recharge infiltration pond near Burdekin River, Qld, part of Australia's oldest and largest MAR system (45 hm^3/year)

Burdekin well for irrigation of sugar cane with recovered groundwater

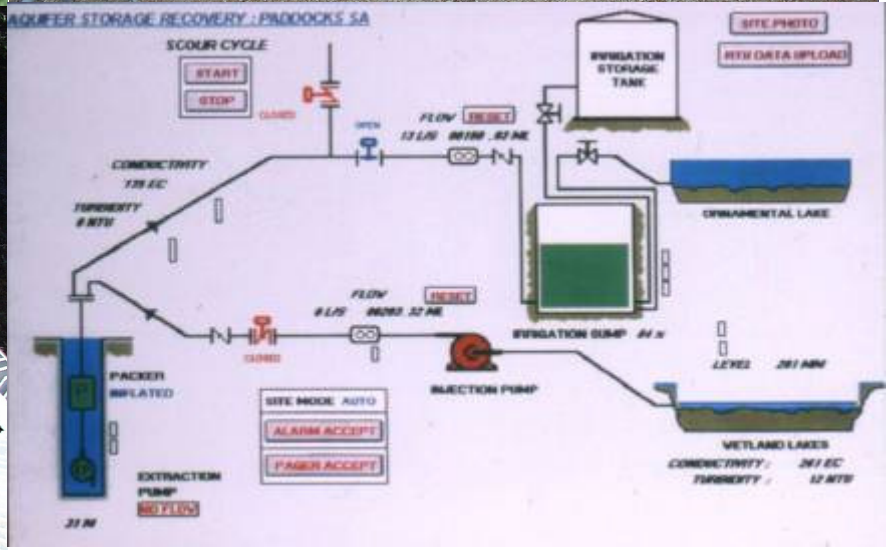
Stormwater ASR development in South Australia

1980's Langhorne Creek – freshening brackish wells by recharge an ephemeral creek

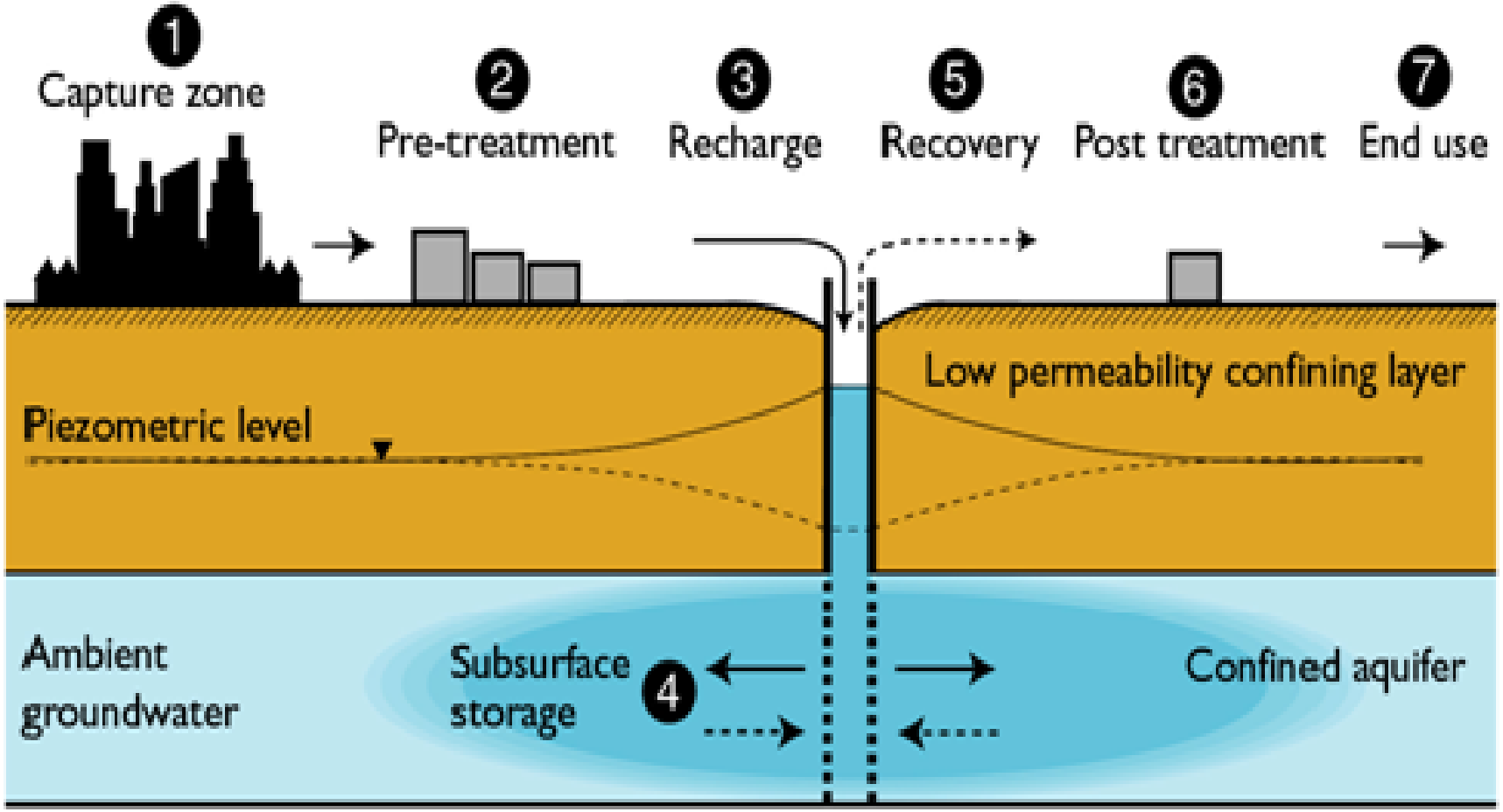


Research commenced 1992: Suburban stormwater ASR (Andrews Farm subdivision)

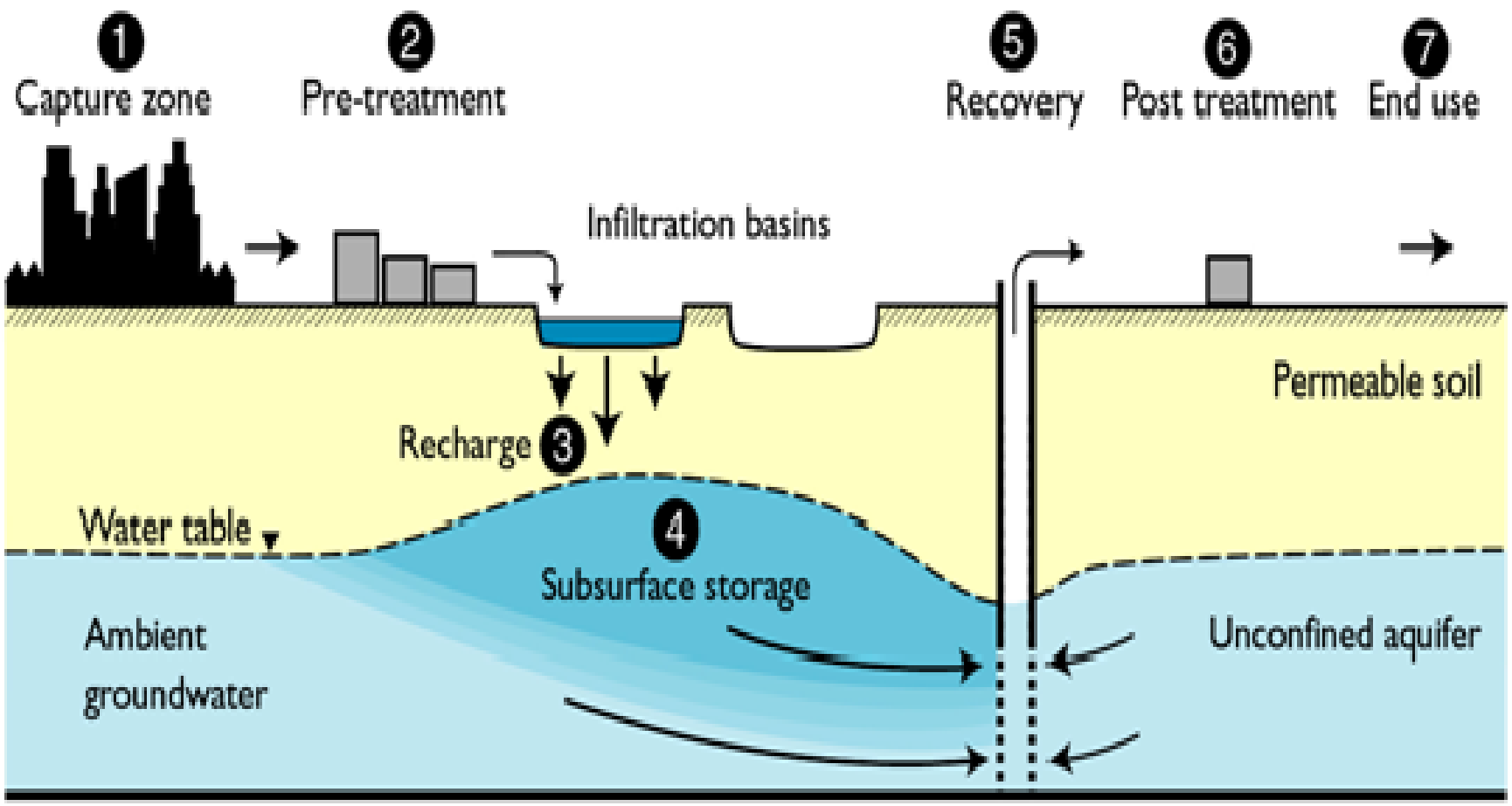
The Paddocks Wetland ASR for irrigation of ovals (City of Salisbury)



Confined Aquifer – aquifer storage and recovery



Unconfined Aquifer – soil aquifer treatment



Water treatment depends on end use of recovered water for any source of recharged water

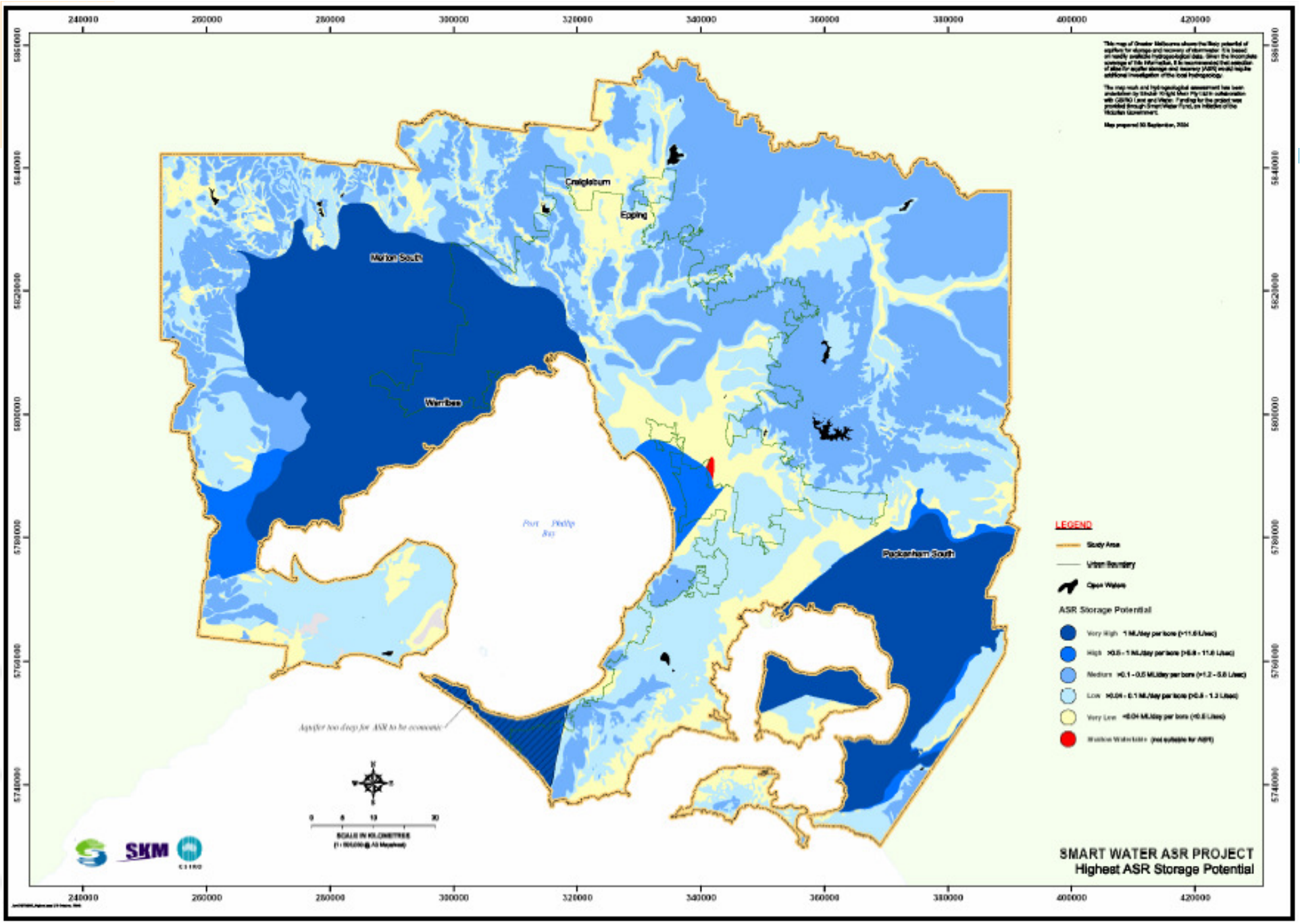
Water source	① Capture	② Water treatment before recharge	③ RECHARGE	④ AQUIFER STORAGE	⑤ RECOVERY	⑥ Post treatment	⑦ End use
Mains water	Tap into mains pipe	None or filter				Disinfection	Drinking water
Rain water	Tank	Filter				None	Industrial water
Stormwater	Wetland or basin	Wetland, MF, GAC				None	Irrigation
Reclaimed water	Pipe from water reclamation plant	DAFF, RO				None	Toilet flushing
Rural runoff	Wetland, basin or dam	Wetland				None	Sustaining ecosystems
A different aquifer	Pump from well	None					

Factors that assist MAR implementation

1. maps showing the availability of suitable aquifers
2. local demonstration projects and information sharing
3. guidelines on MAR to protect health & environment
4. water allocation policies that account for MAR
5. unified water resources planning and management
6. effective community engagement
7. Capability building – training in how to do

Factors that assist MAR implementation

1. **maps showing the availability of suitable aquifers**

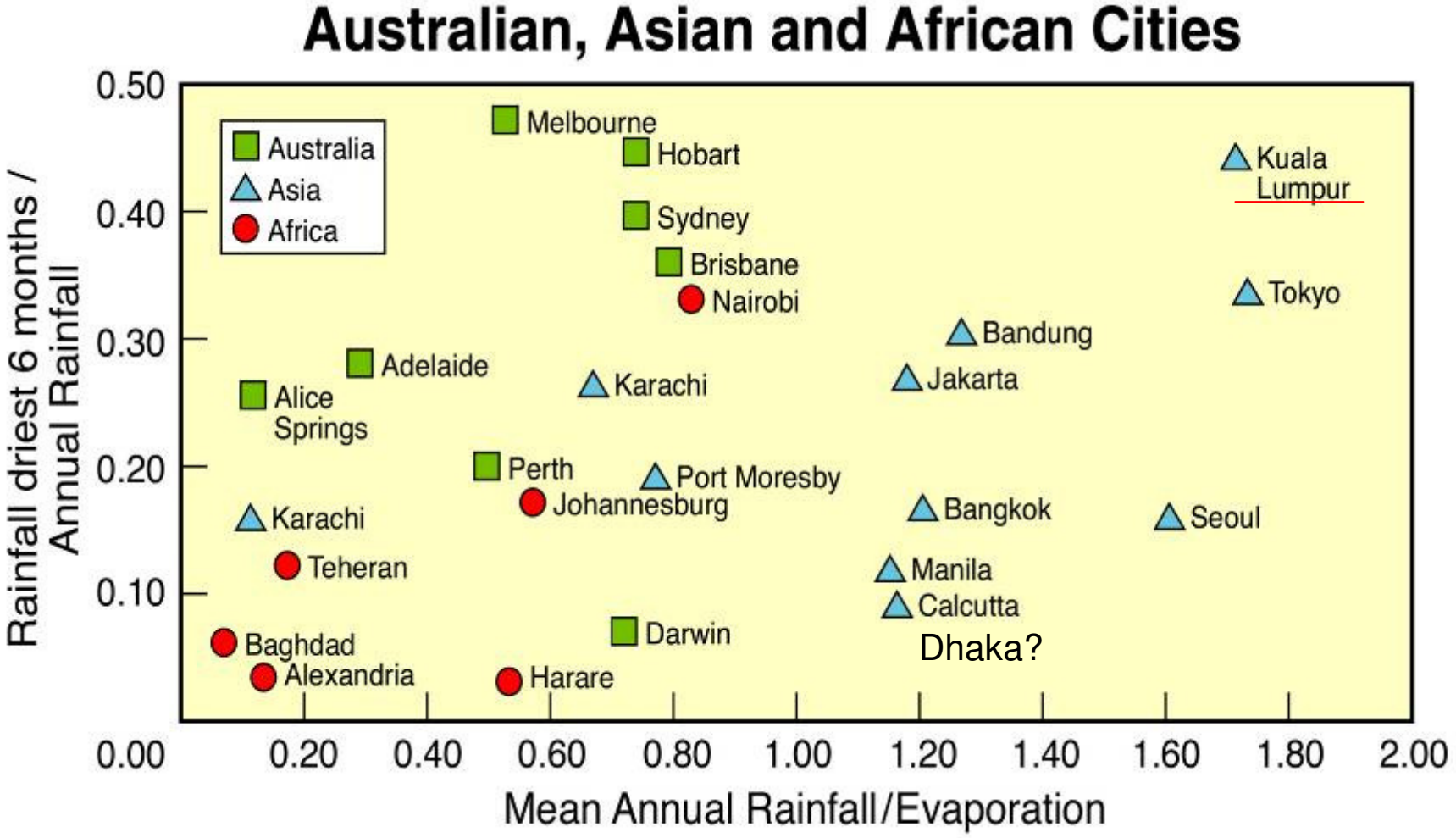


Combined map showing best storage potential from all aquifers

National Research FLAGSHIPS CSIRO

Forecast availability of water of need for inter-seasonal storage – one indicator of potential demand for MAR

← Increasing need for inter-season storage



Increasing availability of water for harvesting →

National Research FLAGSHIPS CSIRO

Factors that assist MAR implementation

1. maps showing the availability of suitable aquifers
2. **local demonstration projects and information sharing**

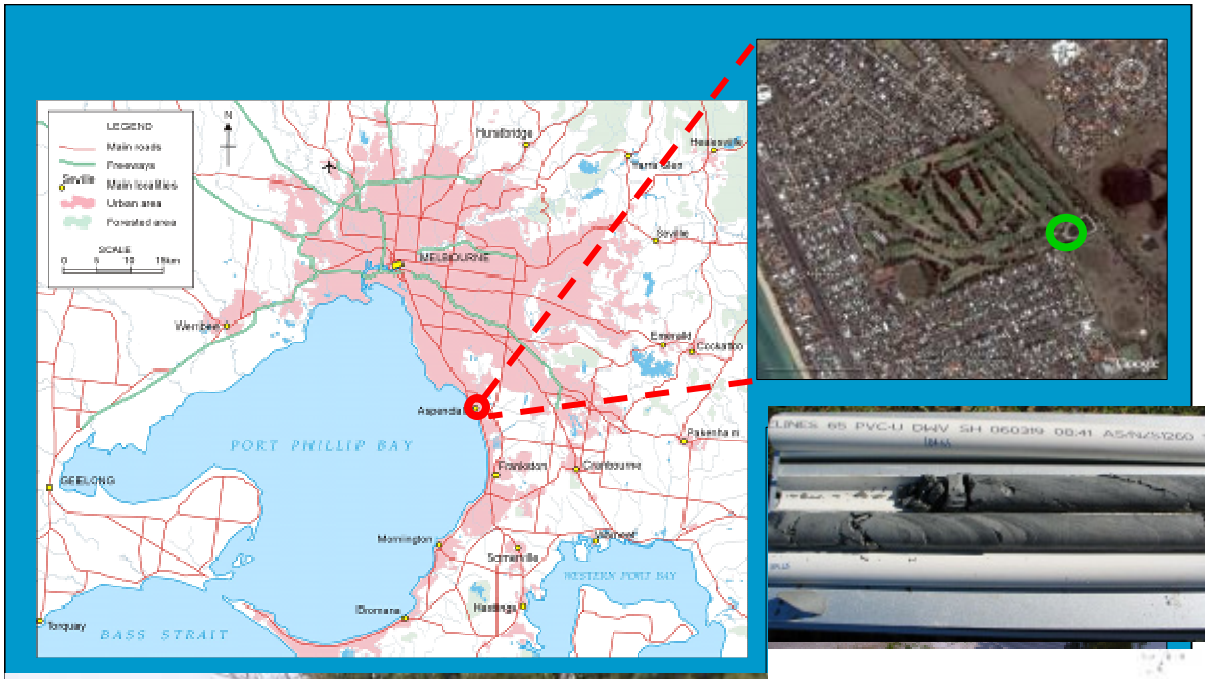
Stormwater ASR for industral water supplies (Salisbury, SA)

Groundwater ASR for drinking water supplies at Warruwi, NT

Smart Water Fund
CSIRO

SKM

Filtered stormwater ASR into hardrock (Melbourne)



‘Aquifer’ cores
K= 0.1 m/d

Stormwater harvesting

uF and GAC filtration

ASR controls and well

Bolivar reclaimed water ASR research project

SA Water's Bolivar DAFF water reclamation plant

Virginia pipeline pumping station

ASR Injection well

National Research FLAGSHIPS CSIRO

ASR with stormwater to dilute reclaimed water (treated sewage) for non-potable supplies

An ASR well for stormwater storage at Greenfields

Greenfields mixing tank for stormwater and reclaimed water for 3rd pipe supply to Mawson Lakes

Construction of Infiltration Galleries, Floreat Park, Western Australia, 2005

Reclaimed water from Subiaco sewage treatment plant is infiltrated in galleries.

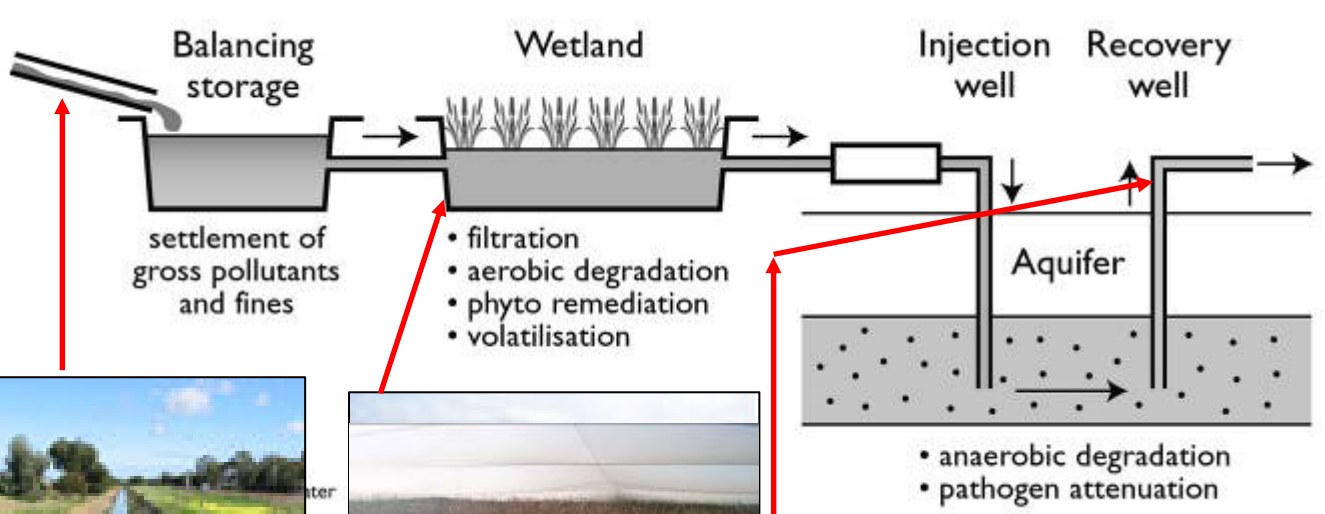
Alice Springs Soil Aquifer Treatment

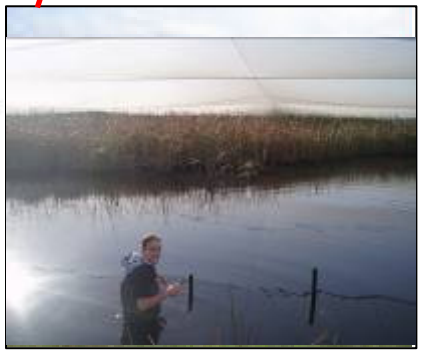
Water reclamation plant

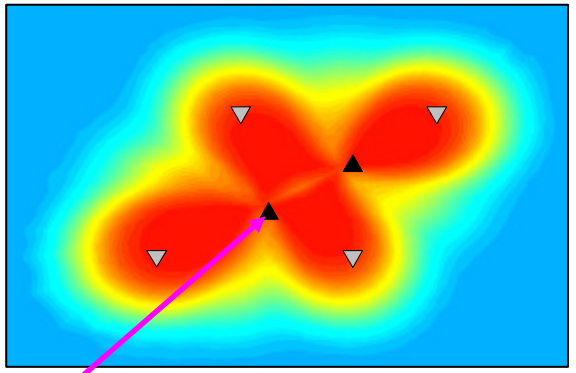
SAT basins first fill in June 2008

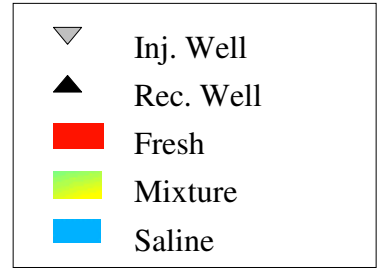
Photo by NT Power and Water

ASTR: Stormwater to drinking water project







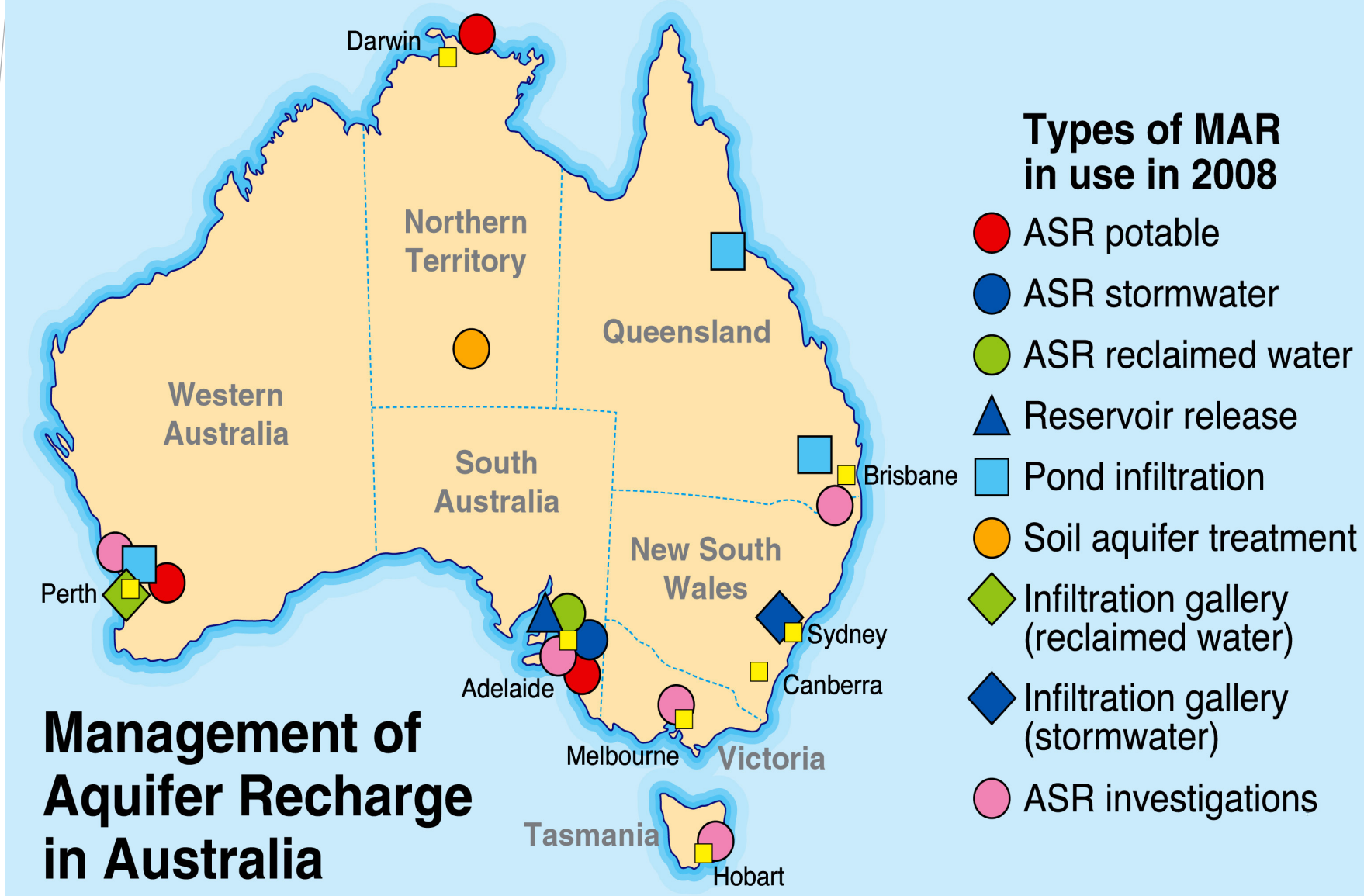


www.clw.csiro.au/astr

astr
aquifer storage transfer & recovery

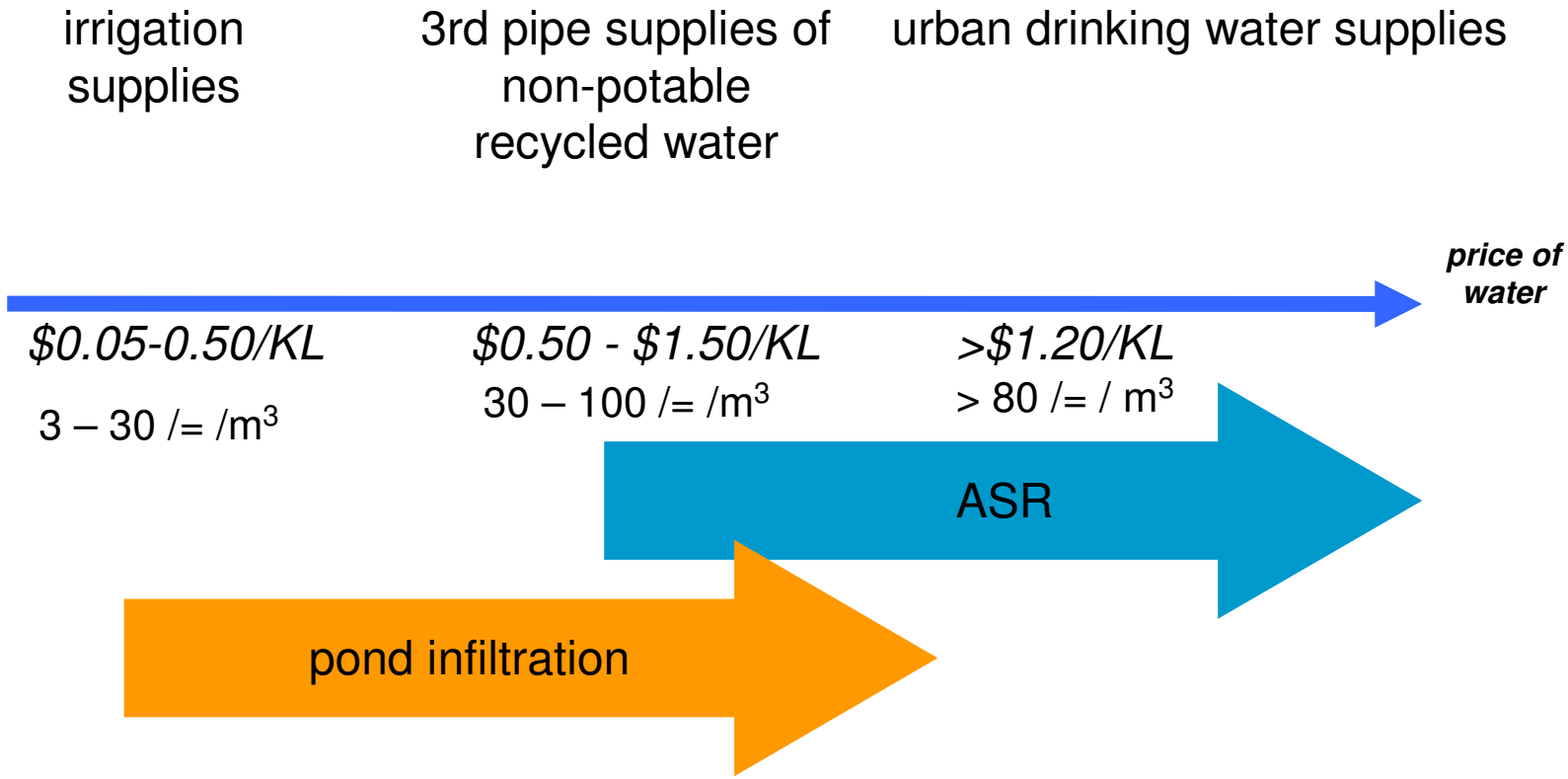
National Research FLAGSHIPS CSIRO

Locations and types of MAR in Australia in 2008



Cost scale of MAR in relation to typical costs of water supplies for irrigation, non-potable & drinking water supplies

/= .. Bangladesh Taka



Dillon, P., Pavelic, P., Page, D., Beringen H. and Ward J. (2009) Managed Aquifer Recharge: An Introduction, Waterlines Report No 13, Feb 2009. http://www.nwc.gov.au/www/html/996-mar--an-introduction---report-no-13--feb-2009.asp

Economics of stormwater ASR compared with seawater desalination

	Seawater Desalination Plant (mean of two)	Stormwater ASR	Stormwater ASR as % of desal. unit costs
Levelised cost* (A$/KL) **(/= /m³)**	3.2 **220**	1.12 **78**	**37%**
Unit energy cost (kWh/KL)	**4.7**	**0.10**	**<3%**

* 15 yrs replacement; 7 per cent interest

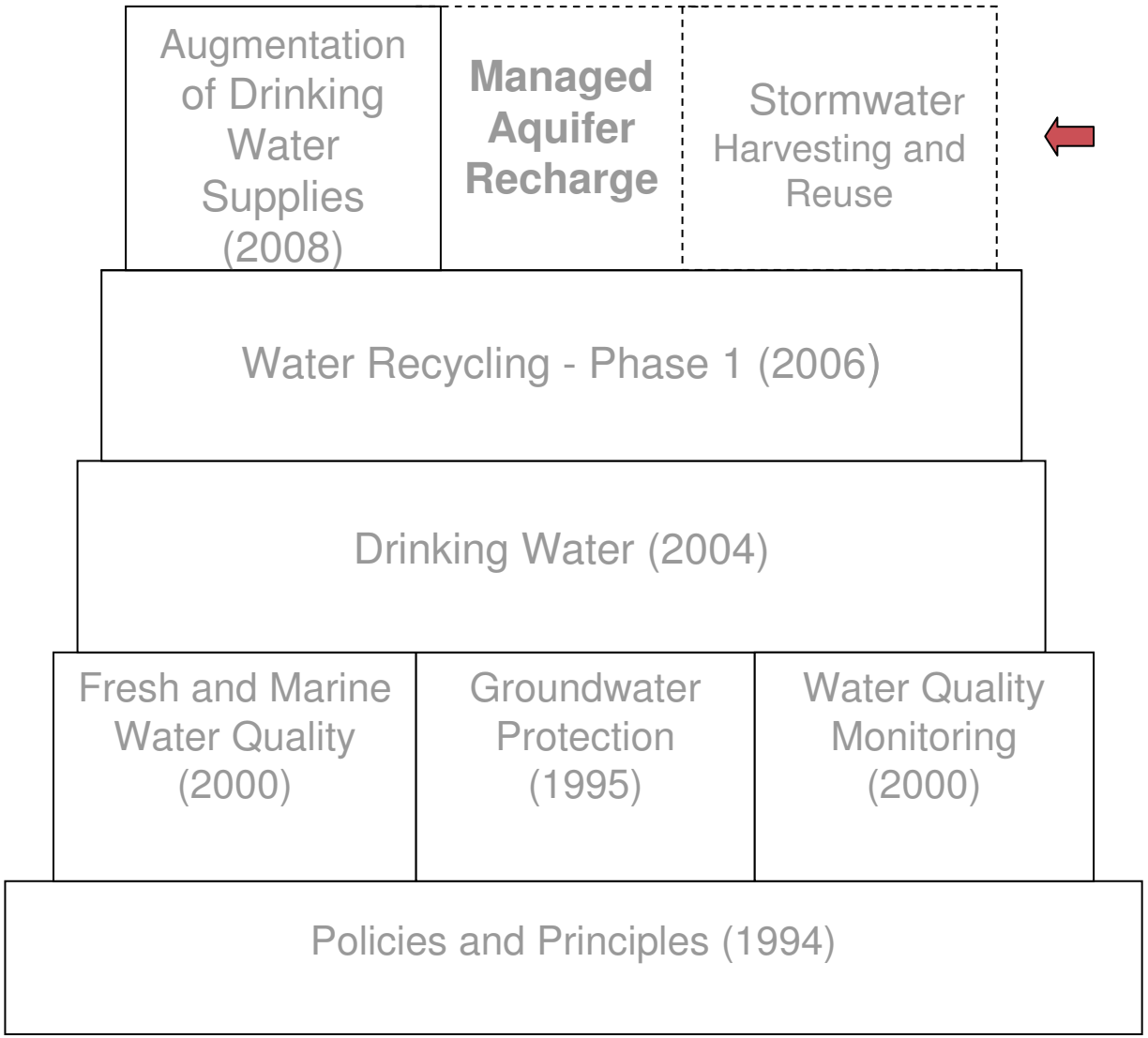
National Research FLAGSHIPS CSIRO

Factors that assist MAR implementation

1. maps showing the availability of suitable aquifers
2. local demonstration projects and information sharing
3. **guidelines on MAR to protect health & environment**

   www.ephc.gov.au/taxonomy/term/39

National Water Quality Management Strategy



Water Recycling Phase 2

parallels WHO Water Safety Plans

National Research FLAGSHIPS CSIRO

Overview of Guidelines

- Risk Assessment and Environmental Values
- What aquifers do and don't do
- Attenuation zones
- Stages in Establishing a MAR project
- Simplified Assessment
- Entry Level Assessment
- Hazards
- Examples of risk assessment criteria, preventive measures, monitoring
- Operational issues
- Summary

Key hazards in source water, groundwater and aquifer materials for MAR projects

Guidelines	Hazard
5.1	Pathogens
5.2	Inorganic chemicals
5.3	Salinity and sodicity
5.4	Nutrients
5.5	Organic chemicals
5.6	Turbidity/particulates
5.7	Radionuclides
5.8	Pressure, flow rates, volumes and levels
5.9	Contaminant migration in fractured rock & karstic aquifers
5.10	Aquifer dissolution and aquitard and well stability
5.11	Impacts on groundwater (dependent) ecosystems
5.12	Greenhouse gases

What soil and aquifers do (depending on local conditions)

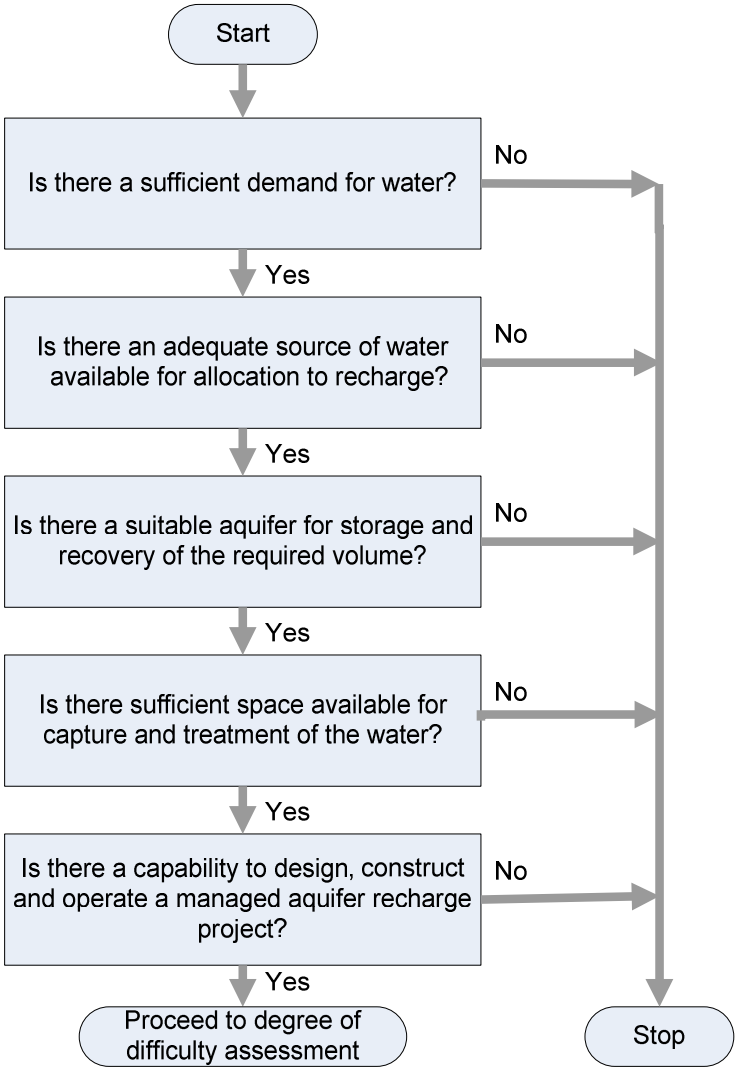
- Hazard removal - sustainable (up to limits) - allow for aquifer attenuation
  - Pathogen inactivation
  - Trace organic biodegradation
  - Nutrient assimilation
- Hazard removal – unremoved or removal unsustainable - these hazards to be removed prior to recharge
  - Salinity
  - Adsorption of metals, organics, entrapment of suspended solids, excessive nutrients
- New hazards introduced by aquifer interaction – change quality of recharge water to avoid these
  - Metal mobilization, radionuclides, salinity, sodicity, hardness, hydrogen sulphide

For each hazard, guidelines document :

- Effect of hazard on public health and environment
- Source or cause of hazard
- Management of hazard
- Tables of
  - Acceptance criteria at different levels of risk assessment
  - Preventive measures
  - Validation monitoring
  - Verification monitoring
  - Operational monitoring

Entry Level Assessment:

1. Viability

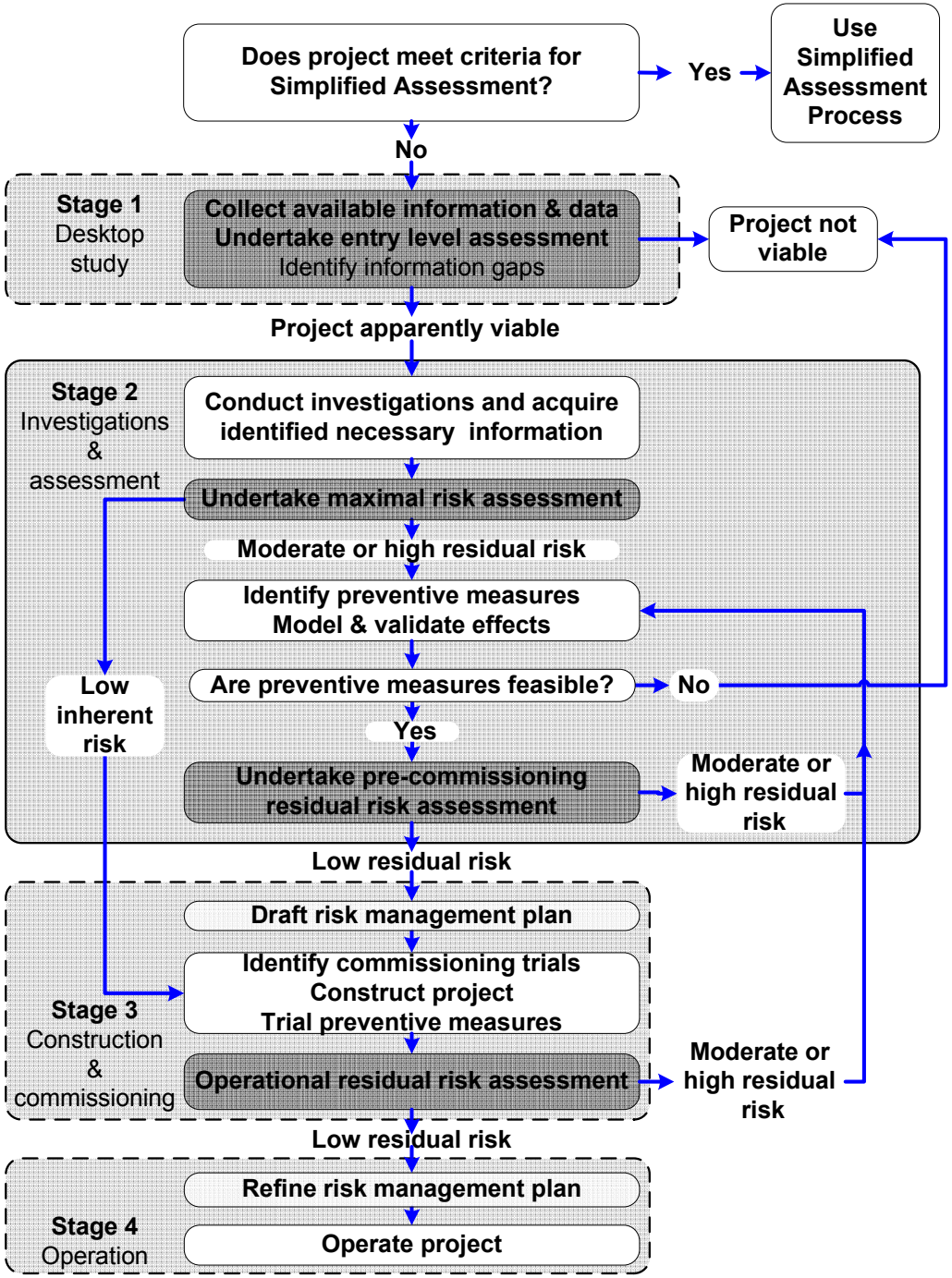


2. Degree of difficulty

14 questions to indicate likely effort in investigations and in managing the operation to ensure protection of human health and the environment

National Research FLAGSHIPS CSIRO

Stages in establishing a MAR project including risk assessment (MAR Guidelines, 2009)
http://www.ephc.gov.au/taxonomy/term/39



Managed Aquifer Recharge - Risks to Groundwater Dependent Ecosystems - A Review

Water for a Healthy Country Flagship Report to Land & Water Australia, May 2009

www.clw.csiro.au/publications/waterforahealthycountry/2009/wfhc-managed-aquifer-recharge-risks.pdf

Flinders University Adelaide • Australia

Government of South Australia

SA Water

RPS

SKM

Australian Government
Land & Water Australia

National Research FLAGSHIPS CSIRO

Guidance on operational issues specific to MAR

Guidelines	Issue
6.1	Clogging
6.2	Recovery efficiency
6.3	Interactions with other groundwater users
6.4	Protection against saline water intrusion
6.5	Operations designed to protect groundwater dependent ecosystems (GDEs)
6.6	Management of purge water, basin scrapings and water treatment by-products

Summary _ MAR Guidelines

- Based on firm NWQMS foundations
- Allow stage-wise development because not all risks can be known in advance
- At each stage preventive measures are used to mitigate risk
- Known aquifer processes that change water quality are accounted for
- A web-site was established to post risk assessments for case studies (Dec 2010) http://www.clw.csiro.au/publications/waterforahealthycountry/2010/wfhc-MAR-case-study-risk-assessments.pdf
- Monitoring is required during commissioning and operation (validation, verification and operational)
- Information generated will be of value in updating these Guidelines in due course

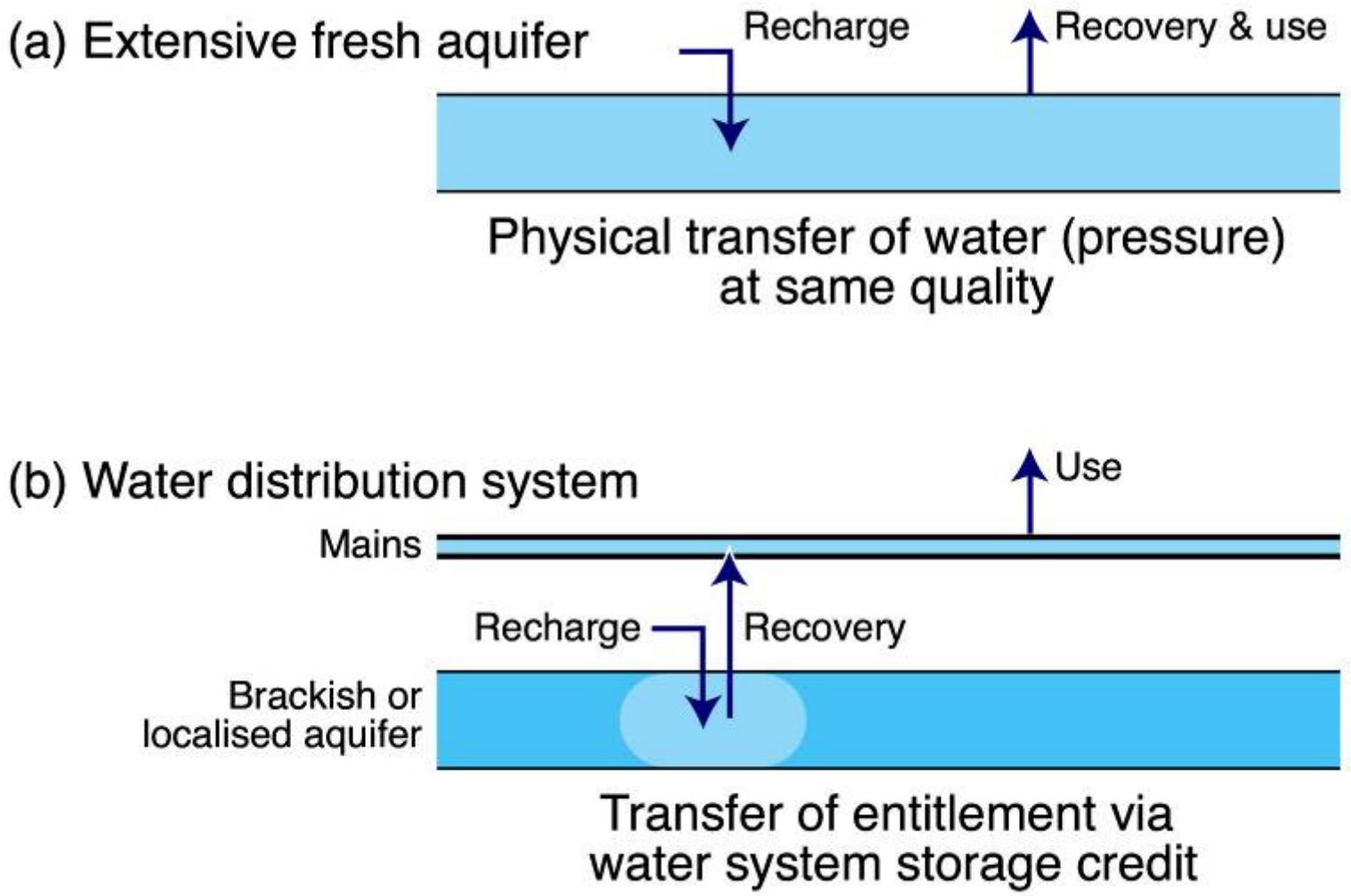
Factors that assist MAR implementation

1. maps showing the availability of suitable aquifers
2. local demonstration projects and information sharing
3. guidelines on MAR to protect health & environment
4. **water allocation policies that account for MAR**

Water policy framework accounting for MAR

Governance Instrument	***Water Harvesting***	***Recharge***	***Recovery***	***Use***
Entitlement	Sharing rule (access to source water)	Sharing rule (aquifer storage capacity)	Tradable sharing rule	-
Periodic Allocation	Rule to adjust allocations	Adjustment rule	Adjustment rule	-
Obligations	3rd party rights of access	3rd party rights	3rd party rights	Use obligations (purpose, efficiency)

Transfer of water entitlements generated by MAR

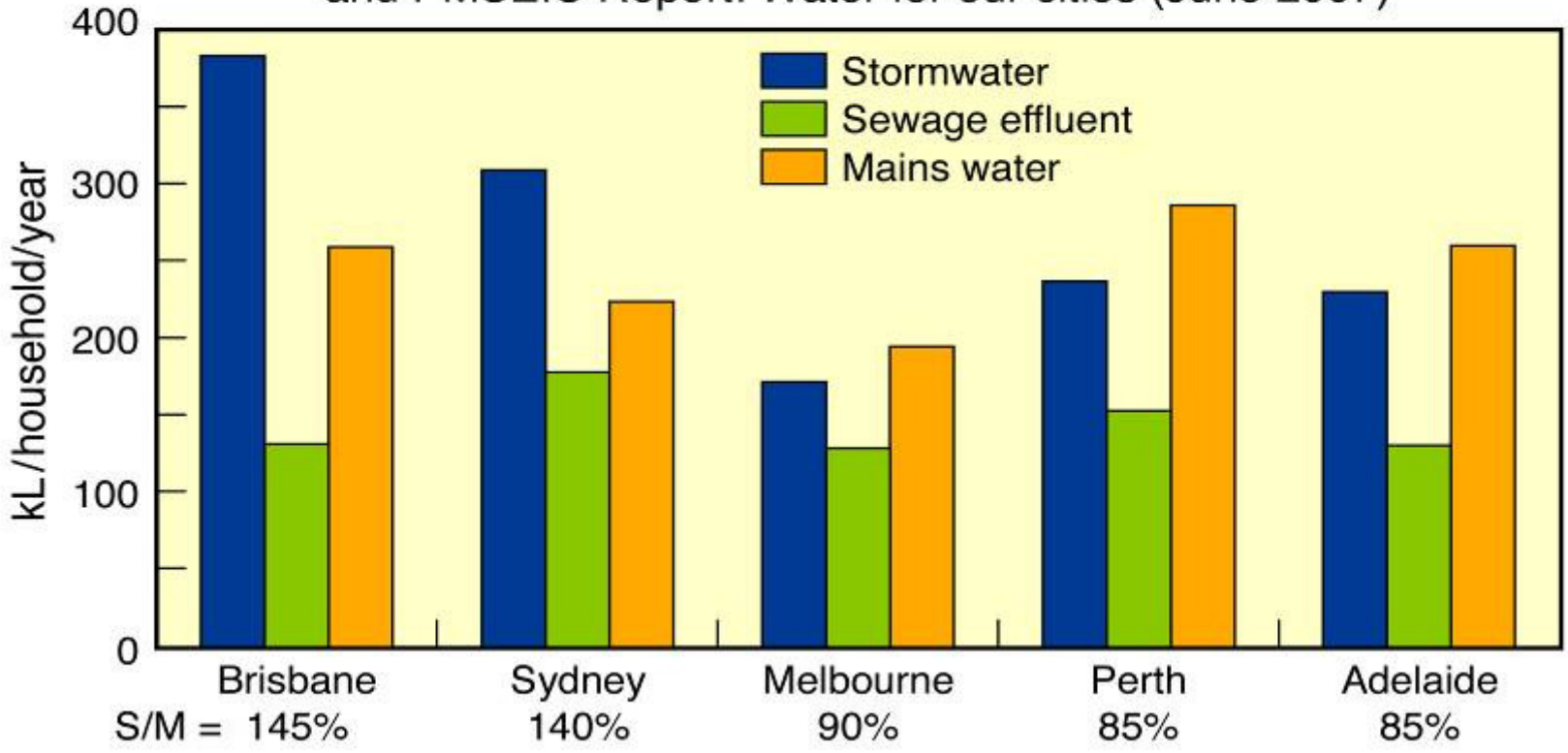


Factors that assist MAR implementation

1. maps showing the availability of suitable aquifers
2. local demonstration projects and information sharing
3. guidelines on MAR to protect health & environment
4. water allocation policies that account for MAR
5. **unified water resources planning and management**

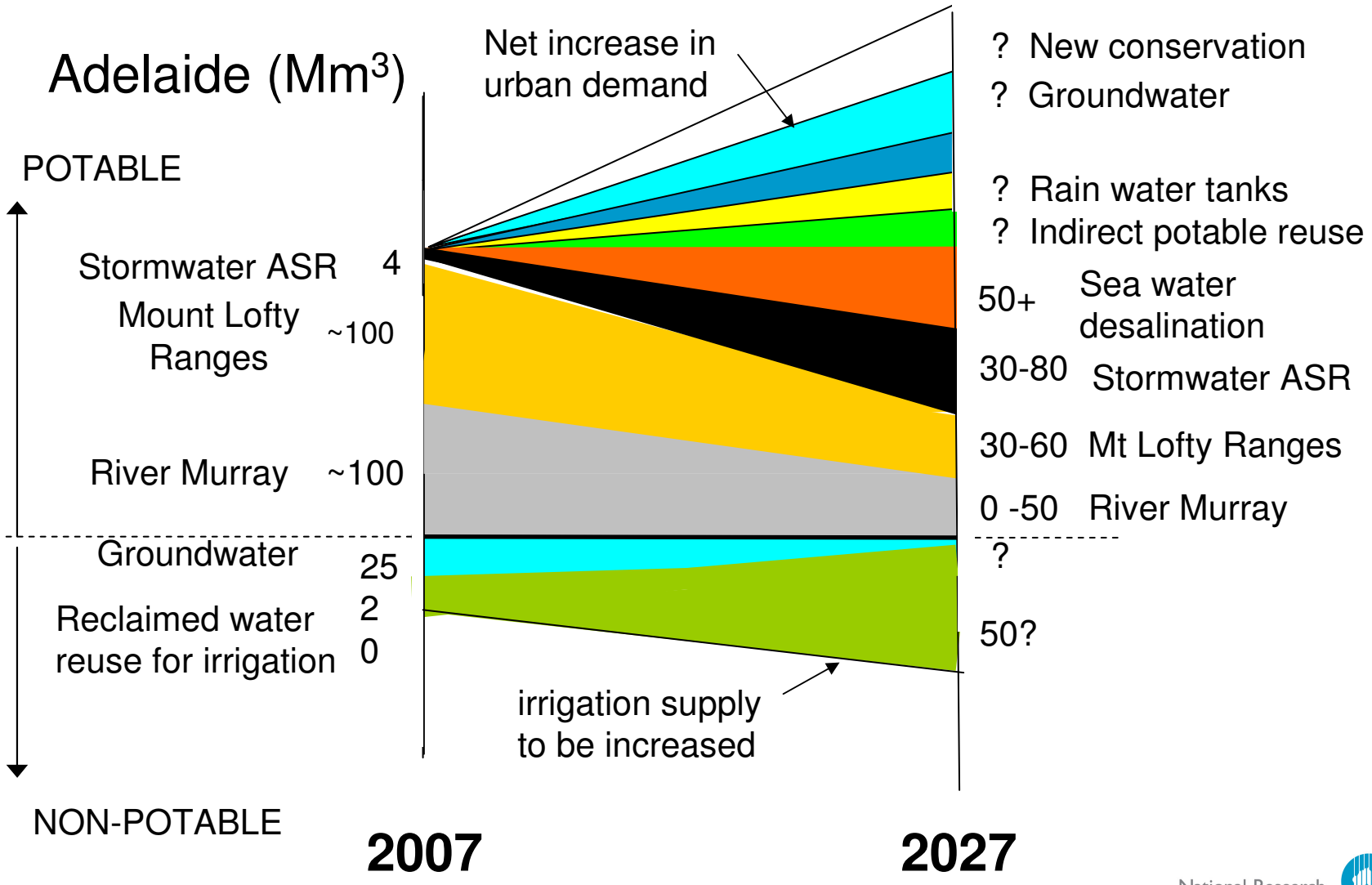
Residential water balance per household

(adapted from Coombes & Barry 2007)
and PMSEIC Report: Water for our cities (June 2007)



National Research FLAGSHIPS CSIRO

Diversified sources of water for Adelaide



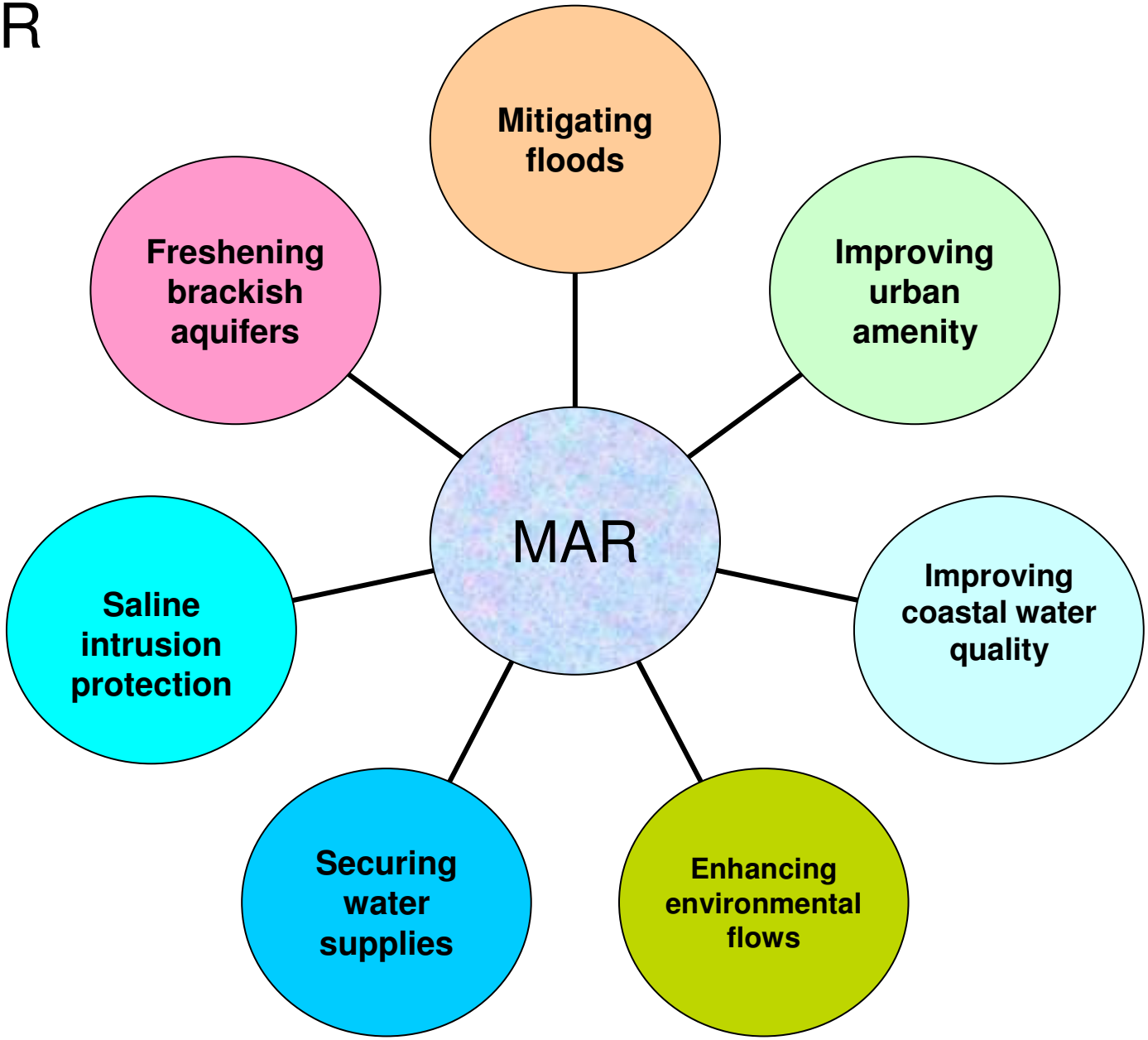
National Research FLAGSHIPS CSIRO

In a diversified portfolio each option contributes to a range of social & environmental objectives

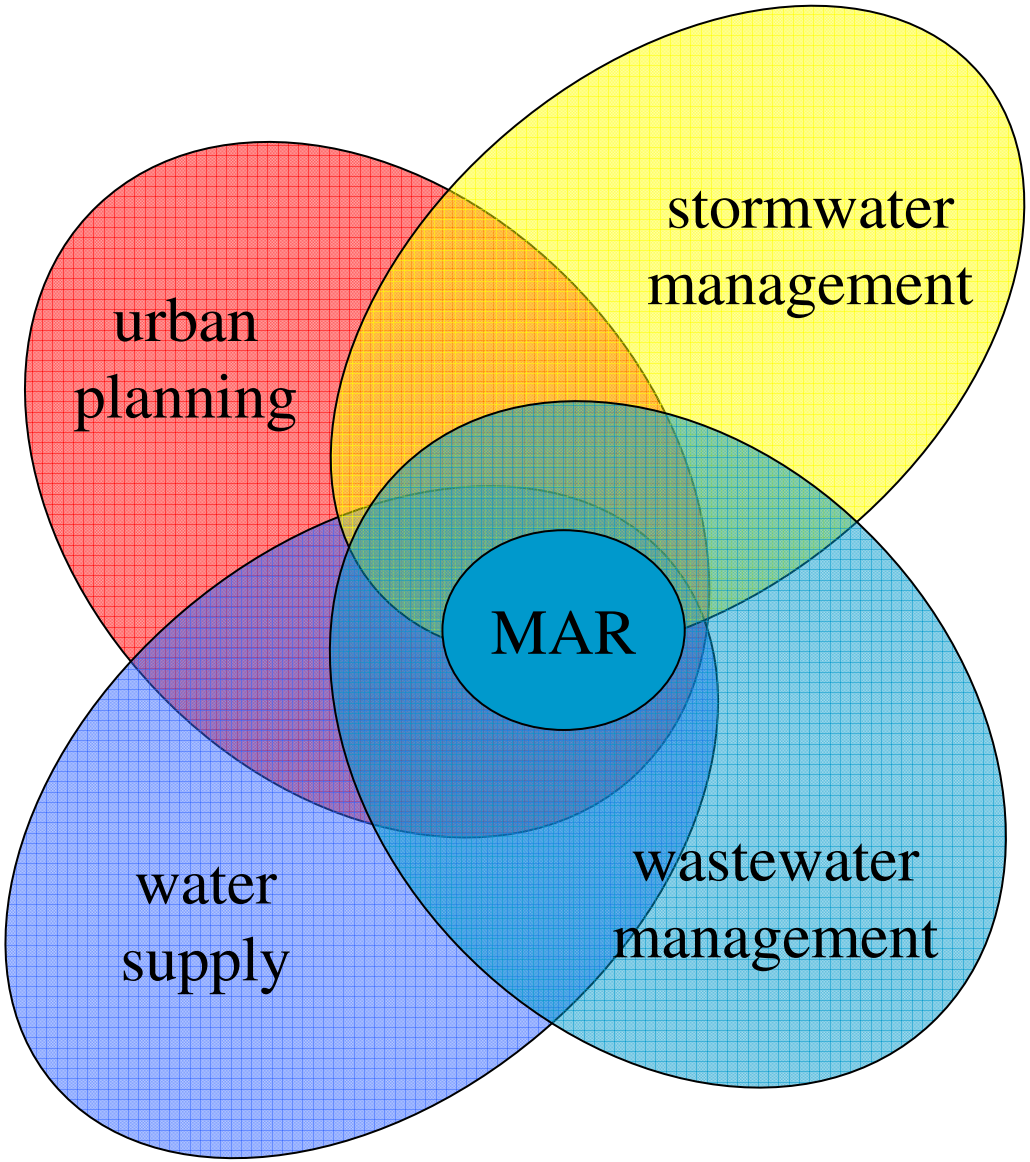
Objective

- Potential volume of supply or saving
- Low unit cost of water sourced or saved
- Improved security of supply – non-reliance on rainfall
- Reduced demand on existing catchments
- Improved coastal water quality
- Reduced greenhouse gas emissions
- Reduced urban flooding
- Improved amenity and land value

Economic, social and environmental benefits and costs of MAR



MAR in urban water management



National Research FLAGSHIPS CSIRO

Factors that assist MAR implementation

1. maps showing the availability of suitable aquifers
2. local demonstration projects and information sharing
3. guidelines on MAR to protect health & environment
4. water allocation policies that account for MAR
5. unified water resources planning and management
6. **effective community engagement**

Effective community engagement

- Consortium partners contribute according to the benefits they derive and their capacity to contribute (Australia)
- Employment program, watershed management, urban renewal, and greenhouse gas reduction programs (India)
- NGOs promoting water conservation, soil conservation, health and agricultural development (India)
- Community consultation is mandatory (Australia)

Factors that assist MAR implementation

1. maps showing the availability of suitable aquifers
2. local demonstration projects and information sharing
3. guidelines on MAR to protect health & environment
4. water allocation policies that account for MAR
5. unified water resources planning and management
6. Effective community engagement
7. **Capability building – training in how to do it**

Capability building – training in how to do it

- Invest in undergraduate and postgraduate students in hydrogeology
- Have students participate in MAR Demonstration projects and monitoring to assess their performance
- Generate research projects across sites to build understanding of each aspect
- Engage regulators in research so they develop capability
- Support by donor agencies and governments to invest in monitoring of impacts of projects, and to devise economically justified sustainable implementation and dissemination programs.

Conclusions

- Because MAR is at the interface of jurisdictions and disciplines to get traction in implementation it needs a champion
- Early runs are useful, by targeting sites where MAR is technically viable, there are willing users and skills to implement.
- Compare the benefits and costs of MAR in relation to alternatives. In those areas where it is the most economic option for preserving or enhancing water supplies, government investment is warranted.
- It is expected that MAR will become a foundational water management method that becomes standard practice where it is viable and cost-effective.

IAH Commission on MAR

- www.iah.org/recharge
- Email list (join at ‘contacts’)
- Major reports, web searchable reference database
- Conferences eg ISMAR7 Abu Dhabi, 9-13 Oct 2010 www.ismar7.org and ISMAR8 Beijing, 13-17 Oct 2013
- Working Groups –economic costs and benefits of MAR (Albert Tuinhof is leading this initiative), clogging, water quality improvements in MAR, governance and institutions, UNMDG drinking water, videos, spanish and chinese websites and resources

MAR-NET
UNESCO- IAH MAR MAR Drinking Water Supplies

- Demonstration projects
- Capabilities – investigations, research, construction, operation, maintenance
- Identify MAR opportunities for economic water supply
- Build case for investment in further projects and capacity building

- Wanted – demo projects and capability clusters, trainers (in relevant languages) – Uni Bangladesh Dept of Geology would be ideal hub for Bangladesh but needs resources to implement.

Resources and Conferences on MAR

IAH-MAR web site

(major reports, conference info, join the email list, searchable references)
www.iah.org/recharge

Managed Aquifer Recharge: An Introduction

Waterlines Report No 13, February 2009 (National Water Commission, Australia)
www.nwc.gov.au/www/html/996-mar--an-introduction---report-no-13--feb-2009.asp?intSiteID=1

MAR Guidelines (Aust 2009) http://www.ephc.gov.au/taxonomy/term/39

Case study risk assessments (Dec 2010):
http://www.clw.csiro.au/publications/waterforahealthycountry/2010/wfhc-MAR-case-study-risk-assessments.pdf

Policies for MAR – water allocation aspects of MAR

http://www.nwc.gov.au/www/html/2986-waterlines-38.asp?intSiteID=1

MAR and stormwater use options –
www.clw.csiro.au/research/urban/reuse

National Research FLAGSHIPS CSIRO

Acknowledgements - Project Partners and Supporters

- National Water Commission
- Western Australia Premier's Water Foundation
- Water Corporation (WA)
- United Water International
- SA Water Corporation
- CSIRO Water for a Healthy Country Flagship Program
- SA Dept Water, Land and Biodiversity Conservation
- SA Dept of Administrative and Information Services
- SA Premiers Science and Research Foundation
- DEST (OzAQUAREC, RECLAIM WATER)
- City of Salisbury
- Hickinbotham Group
- Adelaide and Mt Lofty Ranges Natural Resources Management Board
- Smart Water Fund, Victoria
- AWWARF (#2618, 2974, 3034)
- Corollo Engineers, ASR Systems, WateReuse Foundation
- Flinders University of SA
- Curtin University
- University of Western Australia
- University of Wollongong (OzAQUAREC)
- University of New South Wales
- Centre for Groundwater Studies
- Chemistry Centre WA

National Research FLAGSHIPS CSIRO