A Water Use Efficiency Framework for South Africa

SAIAE CPD event
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Overview

- Project background
- The water balance approach
- Guidelines for improved irrigation water management
- Way forward

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Project background

- WRC Project K5/1482/4:
  - "Standards and guidelines for improved efficiency of irrigation water use from dam wall release to root zone application"
- WRC recognised in 2003 already that the efficient use of water by the irrigation sector will become increasingly important
- The project was perfectly timed to investigate the needs of the water users as well as the organisations that are responsible for water management at different levels.

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Project background

- Agricultural water use sector is the largest of all water use sectors in South Africa
  - using an estimated 56% of surface and groundwater yields annually (Backeberg, 2007)
- Increasing expectations from government that the sector should improve efficiency and reduce consumption, in order to increase the amount of water available for, in particular, human domestic consumption.

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Project background

- Great expectations that an increase in efficiency will lead to reduced consumption by agricultural users and thereby "release" some of the annual water yield for use by other sectors
- The expectation was that all irrigation systems' water use efficiency should be assessed in terms of one or more performance indicators which should be compared with benchmarks, and efficiency improved until the benchmark is achieved.

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Project background

- Overall objective:
  - To evaluate appropriate measurement tools, propose best management practices and formulate guidelines to improve conveyance, distribution, on-farm surface storage, field application, soil storage and return-flow efficiency of irrigation water use

Project background

- Issues that had to be addressed:
  - Confusion regarding the definition of "efficiency"
  - Inconsistent application of existing definitions
  - Lack of data to quantify existing definitions
  - Lack of benchmarks to compare recorded data with
- Improved efficiency ≠ reduced consumption
  - This is still not fully understood by many

Project activities

- Baseline study phase
  - Various performance indicators previously used were reviewed
  - irrigation systems evaluated country-wide to obtain data on the current status of irrigation
- Assessment phase
  - Existing best management practices used to assess the current status of irrigation schemes and systems

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Project activities (cont'd)

- Scenario development phase
  - Alternative scenarios were developed for the system components requiring change, and the feasibility of implementing the changes was assessed from technical, environmental and economic perspectives. Models were used for feasibility assessment, making use of available computer programs and data sets.
- Implementation phase
  - Recommendations were made for implementing feasible changes, and guidelines were developed

Project outcomes

- A set of performance indicators with benchmarks was not developed – rather a water balance approach is being promoted as a more meaningful and sustainable approach to improving irrigation water management
- Guidelines have been developed for improving irrigation water management
- The structure and content of the guidelines are based on the lessons learnt locally and internationally during the course of the project

The water balance approach

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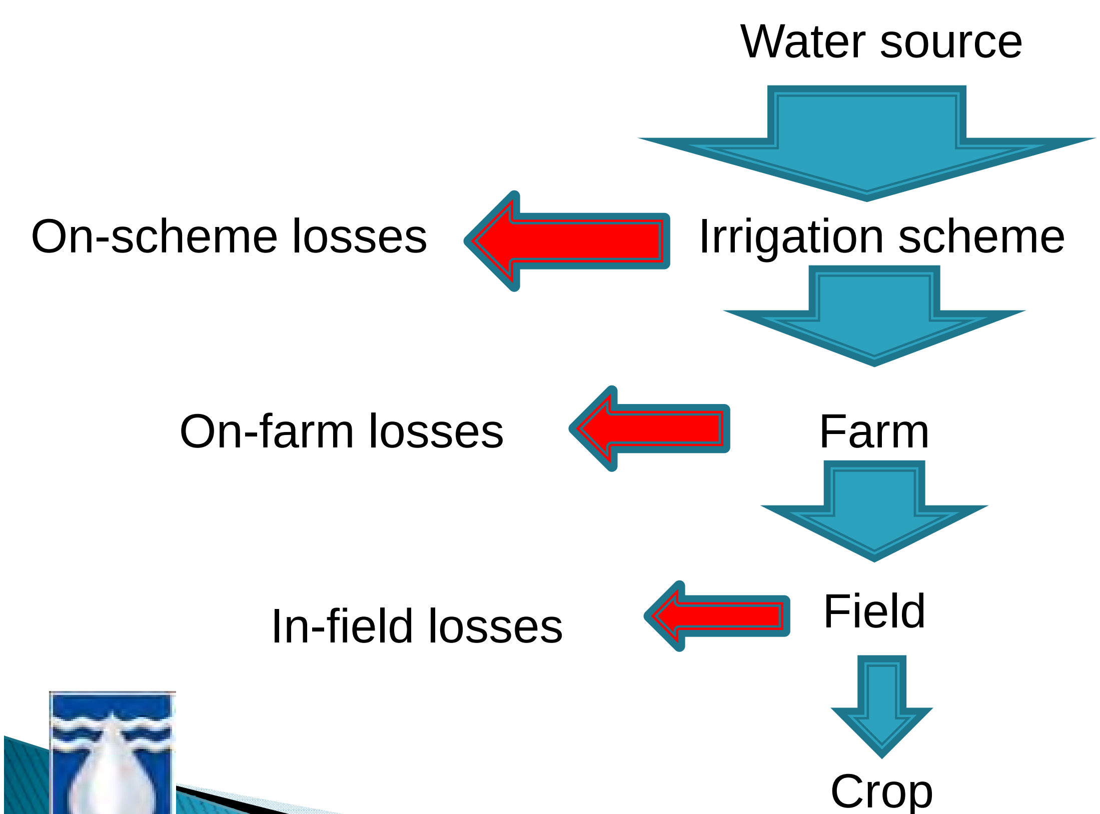
Irrigation Efficiency

- A new approach to defining efficient use of irrigation water:



Ensuring that most of the water taken from the source reach the intended target – the crop – by minimising losses along the way.

A water balance approach

Irrigation efficiency

- Consider a water balance approach rather than calculating ratios
- Taking into account:
  - the intended destination of water taken from a resource, and
  - how the water is used along the way.
- Based on the water use efficiency framework recommended by the ICID and an article published by Chris Perry in 2007

Water balance framework

(Perry, 2007)

Withdrawal for irrigation use:
Water abstracted from streams, groundwater or storage

Storage change: (SC)
Flow to or from aquifers, in-system tanks, reservoirs, etc. With no significant change in water quality between the in and out flows

Consumed fraction:

- Beneficial consumption (BC)
  Water evaporated or transpired for the intended purpose – eg. crop transpiration
- Non-beneficial consumption (NBC)
  Water evaporated or transpired for purposes other than the intended – eg. evaporation from dams, riparian vegetation.

Non-consumed fraction:

- Recoverable fraction: (RF)
  Water that can be captured and re-used – eg. drainage water from irrigation fields
- Non-recoverable fraction: (NRF)
  Water that is lost to further use – eg. flows to saline groundwater aquifers, flow to the sea.

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Water balance framework

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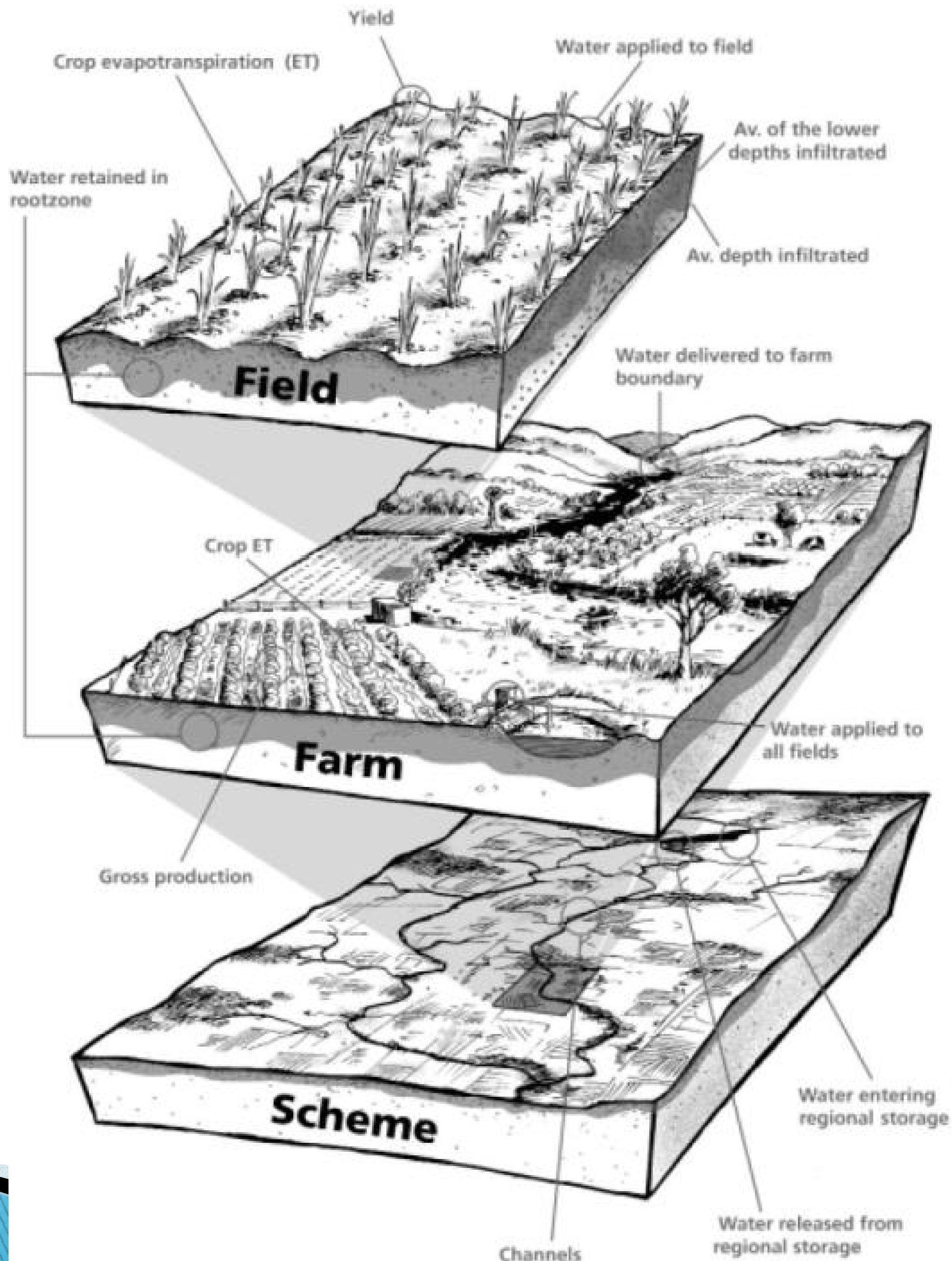

Australian water use efficiency framework (Purcell and Currey, 2003)

Apply to four levels of water management infrastructure:

<table>
<tr><th>Water management level</th><th colspan="3">Infrastructure system component</th></tr>
<tr><td>Water Source</td><td colspan="2">Dam/Reservoir</td><td rowspan="5">Aquifer</td></tr>
<tr><td>Bulk conveyance system</td><td>River</td><td>Canal</td></tr>
<tr><td rowspan="3">Irrigation scheme</td><td colspan="2">On-scheme dam</td></tr>
<tr><td colspan="2">On-scheme canal</td></tr>
<tr><td colspan="2">On-scheme pipe</td></tr>
<tr><td rowspan="3">Irrigation farm</td><td colspan="3">On-farm dam</td></tr>
<tr><td colspan="3">On-farm pipe / canal</td></tr>
<tr><td colspan="3">In-field irrigation system</td></tr>
</table>

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Water balance framework system component (based on infrastructure)	Inflow of water into system component	Possible water destinations within the system component	Framework classification	Desired Range, % of inflow
Dam / reservoir	Total amount of water released from storage	Increase flow in bulk conveyance system (river or canal)	SC	
		Operational losses at the point of release	NRF	<5
River bulk conveyance system (from on-river dam to scheme / farm edge) (if applicable)	Total amount of water entering the river	On-scheme surface storage	BC	
		On-scheme distribution system	BC	
		Farm edge (on-farm surface storage, distribution system or irrigation system)	BC	
		Evaporation from water surface	NBC	<5
		Seepage in river bed	NRF	<10
		Transpiration by riparian vegetation	NBC	<5
		Unlawful abstractions	NBC	0
		Operational losses (unavoidable)	NRF	<10
Canal bulk conveyance system (from on-river dam to scheme / farm edge) (if applicable)	Total amount of water entering the main canal	On-scheme surface storage	BC	
		On-scheme distribution system	BC	
		Farm edge (on-farm surface storage, distribution system or irrigation system)	BC	
		Evaporation from canal	NBC	<1
		Seepage in canal	NRF	<5
		Unlawful abstractions	NRF	0
		Operational losses (unavoidable, eg filling canal, tailends)	RF	<10
		Operational losses (inaccurate releases, spills, breaks.etc.)	NRF	0

Water balance framework system component (based on infrastructure)	Inflow of water into system component	Possible water destinations within the system component	Framework classification	Desired Range, % of inflow
On-scheme surface storage	Total amount of water entering a scheme dam	Increase volume of water stored	SC	
		On-scheme distribution system (release from dam)	BC	
		Farm edge (on-farm surface storage, distribution system or irrigation system)	BC	
		Evaporation from dam	NBC	<1
		Seepage from dam	NRF	<1
		Operational losses (spills)	NRF	<1
Shared (scheme-level) groundwater aquifer compartment	Total aquifer recharge	Increase groundwater storage	SC	
		Farm edge (on-farm surface storage, distribution system or irrigation system)	BC	

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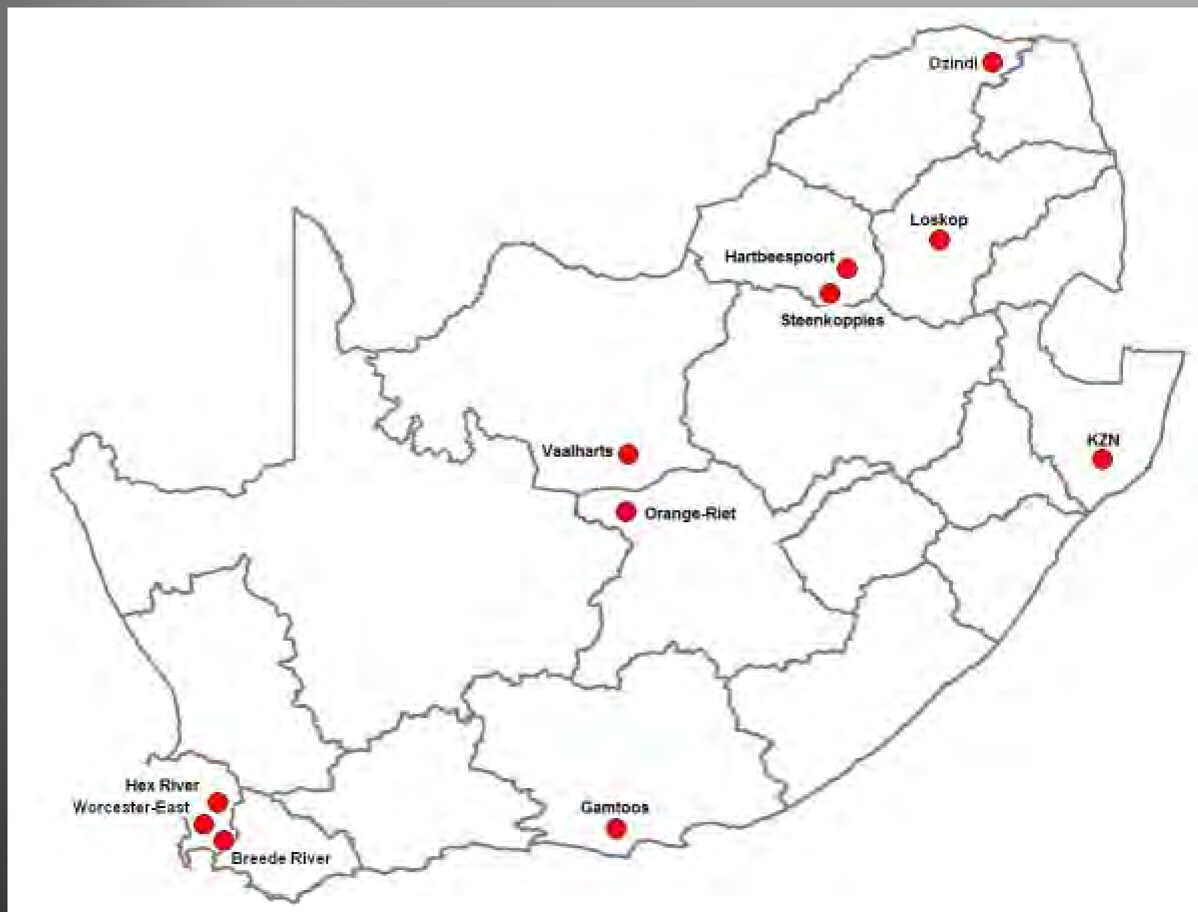
Water balance framework system component (based on infrastructure)	Inflow of water into system component	Possible water destinations within the system component	Framework classification	Desired Range, % of inflow
On-scheme canal distribution system (if applicable)	Total amount of water entering the on-scheme canal distribution system	Farm edge (on-farm surface storage, distribution system or irrigation system)	BC	
		Evaporation from canal	NBC	<1
		Seepage in canal	NRF	<5
		Unlawful abstractions	NRF	0
		Operational losses (unavoidable, eg. filling canal, tailends)	RF	<10
		Operational losses (inaccurate releases, spills, breaks,etc.)	NRF	0
On-scheme pipe distribution system (if applicable)	Total amount of water entering the on-scheme pipe distribution system	Farm edge (on-farm surface storage, distribution system or irrigation system)	BC	
		Operational losses (unavoidable)	RF	<5
		Leaks	NRF	0
On-farm surface storage	Total amount of water entering a farm dam	Increase volume of water stored	SC	
		On-farm distribution system (release from dam)	BC	
		Irrigation system (abstraction from dam)	BC	
		Evaporation from dam	NBC	<1
		Seepage from dam	NRF	<1
		Operational losses (spills, leaks)	NRF	<1

Water balance framework system component (based on infrastructure)	Inflow of water into system component	Possible water destinations within the system component	Framework classification	Desired Range, % of inflow
On-farm distribution system	Total amount of water entering the on-farm pipelines or canals	Irrigation system	BC	
		On-farm distribution system leaks	NRF	0
		Operational losses (unavoidable)	NRF	<5
In-field system (from field edge to root zone) *Intended destination of the water released.*	Total amount of water entering the irrigation system (Gross Irrigation Requirement (GIR) plus precipitation)	Increase soil water content	SC	
		Transpiration by crop	BC	
		In-field evaporation (beneficial)	BC	
		Frost protection irrigation water	BC	
		Leaching (intended, beneficial but non-recoverable)	BC	
		Interception (unavoidable)	NBC	<1
		In-field evaporation (non-beneficial, excessive)	NBC	0
		In-field deep percolation (non-intended, non-recoverable)	NRF	0
		In-field run-off (uncontrolled)	NRF	0
		Drainage water (surface & subsurface, recoverable)	RF	
		Operational losses (unavoidable)	NRF	<5

Field work



Dzindi
Loskop
Hartbeespoort
Steenkoppies
Vaalharts
KZN
Orange-Riet
Hex River
Worcester-East
Breede River
Gamtoos

Scheme name	Infrastructure component analysed	Measured Values / Data collected
Breede	Conveyance system – river and canals	25% conveyance losses
	Crop irrigation requirements	Various – for table/wine grapes, peaches
Dzindi	Conveyance system – lined canal	15% conveyance losses
	Crop irrigation requirements	Various – for vegetables
Gamtoos	Conveyance system – combined canal and pipelines	16% conveyance losses
Hartbeespoort	Conveyance system – lined canal	57% conveyance losses
	Sprinkler irrigation	38% System efficiency
KZN scheme	Conveyance system – lined canal	11.4% conveyance losses
	Crop irrigation requirements	Sugarcane
	Sprinkler irrigation	10% in-field losses
	Scheduling strategies	Various yield vs irrigation values
Loskop	Conveyance system – lined canal	20% conveyance losses
Vaalharts	Conveyance system – lined canal	28.4% of inflow unaccountable
	Centre pivot irrigation system	67% system efficiency
Orange-Riet	Conveyance system – combined lined canal and river	12.7% of inflow unaccountable
	Centre pivot irrigation system	77% system efficiency
	Whole scheme water balance	21.8% non-beneficial consumption
Worcester-East	Conveyance system – pipeline	4.3% conveyance losses
	Lawful water use	93% of lawful allocations actually used

Benefits – through better understanding

- More accurate scheduling
- Improved soil health
- Earlier detection of irrigation maintenance needs
- Optimised on-farm water use
- Monitoring of irrigation scheme infrastructure
- Prioritisation of repairs and improvements
- Improved scheme operation
- More fair and equitable water allocation

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Efficiency Guidelines

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Optimising water use

- We have to find ways of reducing the non-beneficial consumptive and non-recoverable fractions of water use within the areas that we control
- How?

Improvement process

Process:

Quantify water balance components for current situation

↓

Assess WBCs and identify system components to change

↓

Assess feasibility of changing
(Technical, environmental, economic)

↓

Implement changes,
using proven methodologies

Requirements:

Water balance framework and Measurement/Estimation methods

Benchmarks for comparison / assessment

Information on options available
(captured into models)

Guidelines and plans for implementation

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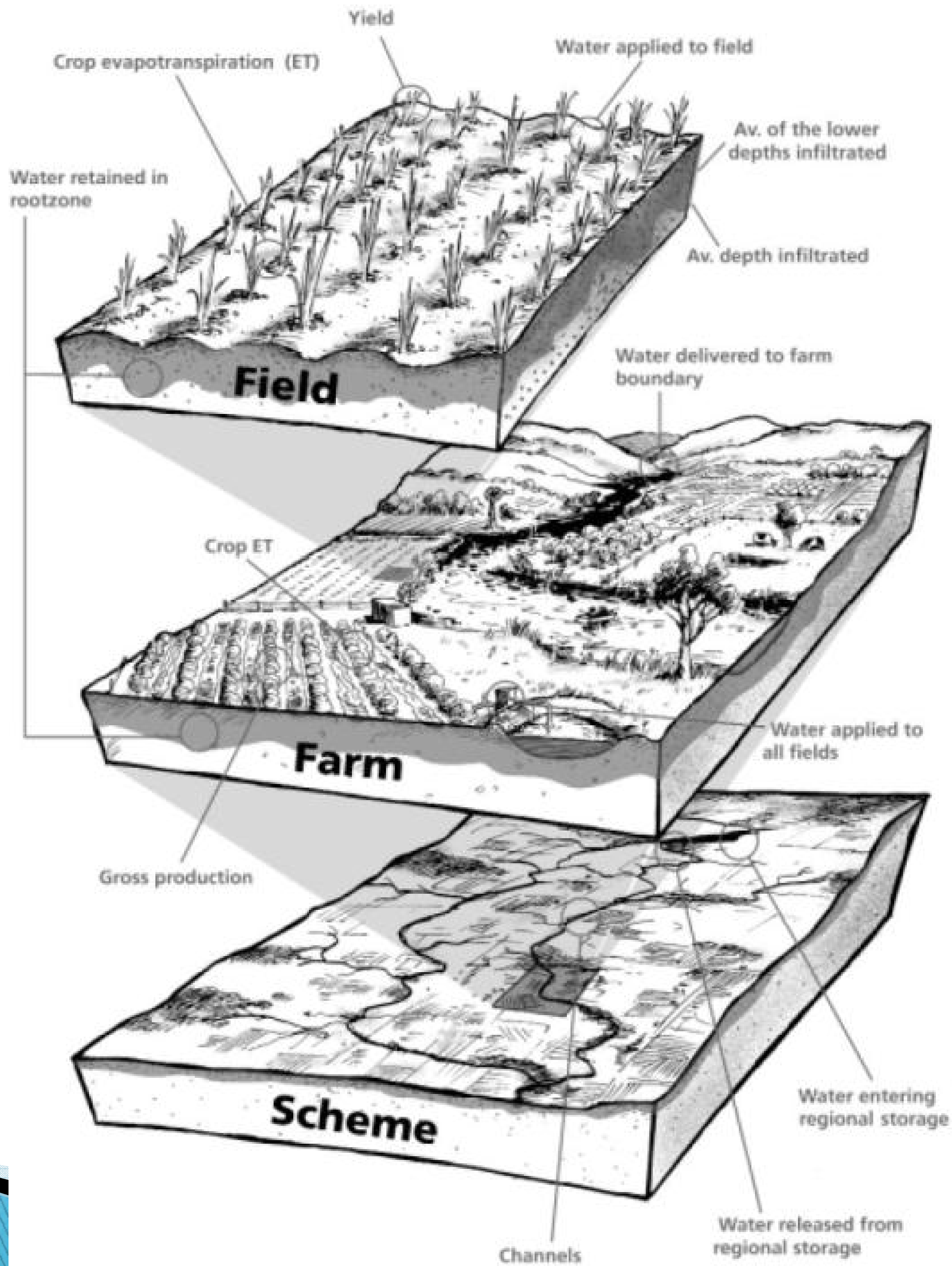
Level of application



Uniformity and accuracy

Energy and economics

Water quantity and quality

Australian water use efficiency framework (Purcell and Currey, 2003)

Guidelines – Module 1

- Fundamental concepts:
  - Lawful water use
  - Water and energy demand management
  - Systems approach
  - Water balance
  - Appropriate technologies

Guidelines – Module 2

- Efficient in-field irrigation systems:
  - Planned with available resources and the water user in mind
  - Designed to apply water uniformly and with low energy requirements
  - Quality irrigation equipment
  - Operated according to specifications
  - Maintained according to recommendations
  - Regularly evaluated for early problem detection

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Guidelines – Module 3

- Efficient on-farm conveyance systems:
  - Planned with capital and operating costs in mind
  - Designed to provide the most economical solution
  - Quality irrigation equipment with high energy efficiencies
  - Operated according to design specifications
  - Maintained according to recommendations
  - Regularly evaluated for early problem detection

Guidelines – Module 4

- Efficient irrigation schemes:
  - All stakeholders have access to information regarding water availability
  - Water use is properly planned not to exceed availability
  - Accurate and reliable measuring devices are installed
  - O&M takes place according to specifications and a WMP is regularly updated supported by a water pricing policy
  - Regular evaluations for early problem detection

Conclusion

Implementation of the water balance approach requires reliable data, which in turn will require:

- Standardised measurements,
- Accurate record keeping,
- Practical models,
- Effective implementation plans, and
- Skilled persons

Way forward

- Development of training material on the water balance approach
- Technology transfer to:
  - CMAs / DWA
  - WUAs
  - Water users

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